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DEFENSE COMMUNICATIONS AGENCY

NMCS TECHNICAL SUPPORT DIRECTORATE

SYSTEM DESCRIPTION

EUROPEAN THEATER NETWORK ANALYSIS MODEL

(ETNAM)

VOLUME IV

PART ONE - DATA BASE

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Vol I - User's Manual
Vol II - Operator's Manual
Vol III - Analytical Manual
Vol IV - Data Base, Part One
Vol IV - Data Base, Part Two

As indicated Vol IV is in two parts. Part Two contains the classified data base, including the transportation networks and related data for BENELUX/West Germany, France, Thailand, South Vietnam and South Korea. Part One (this document) contains background material for the use of the data base, including discussions of the various methods used or proposed for the estimation of capacity of highways, railroads, inland waterways, pipelines, water terminals, beaches and airfields. Resource data on capacity and productivity of the various transportation modes are also included.

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Pipeline Capacity Estimation						
Water Terminal Capacity Estimation						
Port Capacity Estimation						
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SYSTEM DESCRIPTION

VOLUME IV

DATA BASE — PART ONE

EUROPEAN THEATER NETWORK ANALYSIS MODEL (ETNAM)

PREPARED FOR LOGISTICS DIRECTORATE (J-4)

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EUROPEAN THEATER NETWORK ANALYSIS MODEL (ETNAM)

SYSTEM DESCRIPTION - VOL IV

DATA BASE - PART ONE

FOR THE

LOGISTICS DIRECTORATE (J-4), JOINT STAFF

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Enclosure

ILLUSTRATIONS

CHAPTER 1. INTRODUCTION

1. General. The work leading to the publication of the data base on the transportation networks of specifically named countries was [illegible] by the Research Analysis Corporation for the Defense Communications Agency under Contract DCA 100-70-C-0039, Paragraph 3.3 of the [illegible] Task Order No. 006. The work was a part of the National Military Command System Technical Support (NMCSTS) Directorate's overall [illegible] of technical support to the Logistics Directorate (J-4).

2. The European Theater Network Analysis Model.

a. Description. This document is a part of the System Description of the European Theater Network Analysis Model (ETNAM). ETNAM is a [illegible] model providing output for strategic movements analyses based on inter-related considerations of transportation network capacities, [illegible] movement resources, and movement requirements. The model [illegible] transportation modes and routes and then allocates resources so as to maximize flow, minimize cost, or minimize time in accordance with the objectives of the user. The ETNAM is applicable to all theaters.

b. Related Documents. Volume I (User's Manual) and Volume III (Analytical Manual) of the System Description of ETNAM were published in January 1971. These documents may be consulted for a detailed description of the model and for the mathematical and computer processing methods employed.

3. The Data Base.

a. Description. This document is divided into two parts and provides the permanent and semi-permanent environmental data for the analysis of military mobility problems in selected theaters of the world. Part One contains background material for the use of the data base, including discussions of the various methods in use or proposed for the estimation of capacity of the various modes. Part Two contains the classified data base itself for selected countries.

b. Capacity Estimates. With the exception of port capacities in Europe, which were obtained from European port authorities, the capacities of the transportation modes were either computed from standard factor values or were extracted from intelligence documents. There exists convincing evidence that the standard methods of computing capacities for the rail and highway modes considerably underestimate the practical capacities, emphasizing the necessity for reexamining standard methodology in these two areas.

c. Development Requirements. The data base was compiled to satisfy a requirement of the J-4 for data on specified theaters to be used as input to ETNAM. Specifically, Volume IV includes a description of the data base elements; explains existing methodologies for computing network

capacities to assist the user in structuring a network; assembles and documents network data for Central Europe, France, Southeast Asia, and Northeast Asia; develops labels for the nodes of each network; and analyzes and explains factors that influence the productivities of resources. The effort involved was limited to the collection of data that was available in the existing literature.

d. Data Base Elements.

(1) ETNAM data base elements may be divided into two parts: "environmental" or theater-oriented, and "scenario" or problem-oriented. The environmental data base lends itself to retention on a permanent or semi-permanent basis, and is the only one for which data was collected. It consists of the transportation networks of a country, military and host nation transportation resources that may be used on those networks, and the capabilities of those resources.

(2) The problem-oriented data are derived by the model user from information generally presented to the user in the form of a scenario or plan, but which may be simply a number of assumptions or problem conditions. By their nature, these data are not contained in a permanent data base and were excluded. Included are phased movement requirements, percentages of network capacities made available by the host nation, toll coefficients on network links, commodities permissible on specific transport modes, resource substitutions on these modes, origin-destination pairs, development of phased movement requirements, and other input data requiring a user quantification.

(3) The data base itself is contained in Part Two of Volume IV and has been structured to correspond with the requirements of the System Description, Volume III - Analytical Manual, of the ETNAM, January 1971, and is organized around the networks of the specific countries. These networks are portrayed graphically in separate chapters, each devoted to a specific country or area. The characteristics of each link in the networks are listed in the same chapter together with a listing of the host nation's transportation resources, taken from the latest information available.

(4) The links of the transportation networks were chosen for their military value. Secondary roads or canals were not included because of their low capacities. The planner may expand the network data by including these and other existing links by using his own judgment in developing the capacity estimation methodology to be used.

(5) A major portion of Part One is devoted to an explanation of the methodologies employed to estimate capacities of the modal links. Much of the material used in this endeavor is official doctrine adapted to the specific objectives of the data base, and sources are documented throughout.

(6) Available intelligence data sources from which much of the modal capacities were estimated contain some inconsistencies and rarely specify the methodology employed in arriving at the published capacity estimates of transportation modes. In the estimation of highway capacity, the inconsistencies could be attributed to differing values placed on the multiplicative factors used in the current doctrinal formulas and to possible road improvements. Trade magazines were used to update information wherever possible.

(7) Military movement resources for each mode are listed in the chapter discussing that mode in Part One. Capabilities of the military units are the design capabilities contained in official documents. Unit cost data are not included in the data base.

CHAPTER 2. PROBLEM FORMULATION

1. Introduction.

a. The discussion that follows has been adapted from the guidance issued to the intratheater study group within the MOVECAP (70-74) Study. It reflects the thinking of analysts with significant experience in both strategic mobility problems in general and with the ETNAM system in particular. It is included in this document due to its brief and comprehensive summary of the effort required to formulate a problem for ETNAM.

b. Indicated below are the procedural steps, decisions, and quantification of variables that must be accomplished in order to form the necessary data base for inputing a problem to the ETNAM. Adjacent to each procedural step are listed representative factors which must be taken into account in order to satisfactorily bound each step. All the steps, with the exception of Step 1, need not necessarily be accomplished in the order presented in Figure 1.

2. Establishing the Scenario. In establishing the scenario for the contingency area to be examined, the following questions must be answered:

a. Where is the contingency area?

b. What is the force posture?

c. What is the time period to be examined?

d. What is the tactical situation?

e. What is the troop strength to be supported?

The answers to these questions have a direct impact on those factors which must subsequently be addressed in structuring the total problem.

3. Developing the Network. In developing networks of the ETNAM model the following must be considered:

a. What types of networks are desired in the composite network? The model is capable of handling data on air, rail, highway, pipeline, and waterway networks.

b. What is the capacity of each link in the network? The capacity of a link is stated in the total vehicles that may transit that link in a day.

c. What is the length of each link? Each link originates at a FROM node and terminates at a TO node with the distance between stated in miles.

		FACTORS
Step 1	Establish Scenario	Contingency Area Force Posture Time Phasing Deployment Period Tactical Situation Troop Strength
Step 2	Develop the Network	Node Location and Types Capacities of Links Length of Links Commodities Permitted on Links Direction of Flow on Links
Step 3	Assemble Data on Resources	Numbers/Types of Resources Productivities of Resources Costs of Resources
Step 4	Develop Movement Requirements and Origin-Destination Pairs	Cargo Commodities Weights Movement Requirements Origins & Destinations
Step 5	Establish Solution Parameters	Modes Optimization Criteria Mode Speeds

FIGURE 1. SOLUTION STEPS

d. What commodities are permitted to flow across each link? The user has the option of permitting individual commodities, combinations of commodities, or all commodities to transit any given link of the network. For example, troops would be permitted to move over all links of the network with the exception of those making up the pipeline network.

e. How are the nodes to be represented within the overall intra-theater network? The user may model the nodes, and the functions performed there, as miniature networks within the composite network.

f. What direction of flow is permitted on each link? The user may specify for each and every link whether cargo flow is permitted in either direction over the link or in only one direction.

g. What is the tactical situation? The tactical situation assumed in the scenario will dictate the location of the Seaports of Debarkation, Aerial Ports of Debarkation, Forward Air Strips, Transfer Points, and Depots.

4. Assembling Resource Data.

a. What are the types of resources available for use? The user must specify resources which are available for moving each commodity type through the network.

b. What are the numbers of resources available for use? This number may be stated as an actual available inventory or a hypothetically unlimited inventory which will not constrain the problem (used in force sizing type problems).

c. What are the resource productivities? The productivity for each resource type must be stated in terms of its short tons (STONS) capability per 24-hour period, e.g., a truck company might have the capability of moving 1,800 STONS 100 miles in one day.

d. What are the resource costs? The cost per resource type must be stated in meaningful terms at the productivity assigned.

5. Developing Movement Requirements and Origin-Destination Pairs.

a. What are the cargo commodities to be considered? The user must specify the number and types of commodity classes to be moved through the system, i.e., PAX, POL, AMMO, containers, etc.

b. If the link capacities are given in short tons, what is the equivalent weight in (STONS) of the average component of each commodity class? The user must specify this weight for each class of cargo, e.g., the average weight of a container might be determined to be 10 STONS, and the average weight of a break bulk component might be determined to be .6 STON.

c. What are the movement requirements? From the troop strength and force posture developed in the scenario, the user must establish the volume of movement requirements by commodity class, necessary to support the deployed force.

d. What are the origins and destinations of the movement requirements? The user must specify the point or points of origin of the movement requirements and the point or points of their termination.

6. Establishing Solution Parameters.

a. What are the modes to be used? The modes are the various methods of moving cargo from origin to destination, within which are contained the resources i.e., road, rail, air, waterway, and pipeline. The user may identify up to a maximum of twenty modes and may specify modes which portray work unit activities such as loading, unloading, transferring, etc.

b. What is the optimizing criteria? The user may elect to optimize on any one of three criteria: minimum cost, maximum flow, or minimum time.

c. What are the mode speeds? The user must specify the speed in miles per hour that a link lift resource may move in that mode.

CHAPTER 3. DATA BASE ELEMENTS

1. Definition.

a. A data base, for the purpose of this document, is defined as a formatted assembly of all those collectible data, of a permanent or semi-permanent nature, required by ETNAM as input for the solution of those problems for which it was designed. More specifically, the elements of the data base will consist of those transportation data of the environmental or theater-oriented aspects of the intratheater transportation system within selected theaters, and will include problem or scenario-oriented data unique to the problem in hand, such as movement requirements, destinations, and arc tolls.[1]

b. Governed by this interpretation, the data base elements are described below.

2. Transportation Networks.

a. The major surface networks, considered by transportation mode, are highway, rail, inland waterway, and pipeline, and consist of a representation of all physical links in the network, the intersections of which define nodes. When two or more modal networks have a common node, the node becomes a potential transshipment node.

b. Those nodes that interface inter and intratheater transportation systems are called origins with respect to intratheater transport. They are permanent in nature and include the terminals of intertheater transport nodes (i.e., seaports and aerial ports).

c. Certain other nodes, at which requirements exist for men or materiel, are designated as destinations. These are problem-oriented, subject to change during the solution process, and are not included in the data base.

d. The network of the air mode is defined by treating airports as a transportation mode. For consistency seaports are also defined as a transportation mode.

e. Depots, or other storage areas, may be designated as destinations for movement from the rear, and as origins for movement forward, depending on the structuring of the problem.

f. Each node in the system has a unique code number and each link is uniquely designated by the code numbers of the nodes which it connects.

[1] See ETNAM System Description, RAC 1969 (Parts I and II)

g. As long as each node is assigned a unique number, the cards containing data on network links may be input to the computer in any order. The ETNAM system assigns its own internal identifying code to each link. The program sorts all link data records by the FROM node code and they are listed in this order in the input report. If the coding system in this data base is used the list will be in order alphabetically by country, numerically by node number, and alphabetically by mode designation.

3. Major Modes. In intratheater usage there are at present five major modes, i.e., rail, highway, airway, waterway, and pipeline. Depot services are not usually considered as a mode, but depot services do require time and resources that are of interest to the mobility planner. The ETNAM was, therefore, designed to permit depot services to be represented as a mode and a necessary function that must be performed in the process of moving men and materials from the ports of entry to the consuming unit. In order to distinguish the special modes they are referred to in this document as Quasi-modes.

4. Quasi-modes. Quasi-modes are chosen or designated by the planner as necessary for a particular problem, or to analyze specific transportation movements. The number of possible quasi-modes is almost limitless, and can range from the primitive mode/media to the drawing board items in research and development, e.g., pack animals and porters, helicopters, logistic missiles.

5. Link Distance. The distance between nodes in a network is naturally defined for most highway, pipeline, waterway, airway, and rail links as the physical distance to be traveled between nodes. Transfer links between nodes, at transshipment points, present a different problem in that the actual physical distance may be quite small, but the time, effort, and resources required to traverse the link may be large. For mathematical convenience the distance traversed in the transfer link is set equal to one unit of distance. The time, effort, and resources required to accomplish the transfer may be presented by the condition coefficient element described below.

6. Link Capacity.

a. Within the ETNAM model link capacity is simply the maximum flow that is to be permitted over the designated link. This maximum flow may be a careful estimate of the maximum physical flow that may pass over the link under an assumed set of conditions or it may be simply an arbitrary number established by the planner or by other authority. For example, the capacity of a link may be the maximum desired flow as determined by vulnerability or other considerations. Link capacity may be expressed in tons per time period or in vehicles per time period depending on the method chosen by the planner.

b. In most cases the link capacity used in the ETNAM model will be a careful estimate of the physical capacity of the link. Unfortunately

there is no single, universally accepted method of estimating link capacity. Most of the available methods are discussed at length in Chapters 4 to 9, Part One, which cover the major modes of transportation. Chapters 1 to 5, Part Two, contain network maps and supplementary data for each of the covered theaters. In some cases, e.g., South Vietnam, the capacity data comes directly from official sources. In these cases the precise methods used to obtain the capacity data is not known. Data for the European network were developed by Research Analysis Corporation analysts using the accepted U. S. Army techniques as described in FM 55-15.

c. The capacity of a transportation link is a difficult and sometimes controversial concept that is still undergoing change and improvement. A brief discussion of the concept of capacity is contained in the mode chapters (4 through 9).

7. Link Condition Coefficient.

a. The link condition coefficient is used to express the difference between the quality of various links of the same mode and therefore the difference in resource utilization. The use of the arc condition coefficient is perhaps best indicated by example.

b. Two highways may connect city A and city B. One highway may be a four-lane, limited access, first quality road while the other, although shorter in length, is a two-lane, secondary highway with poor surface condition. ETNAM will choose the shorter route although the superhighway is operationally the preferred route. The condition coefficient is provided to resolve this problem.

c. An extensive highway net, as in Europe, is particularly sensitive to the value of the condition coefficient because of the number of competing links. On all other major modes the condition coefficient is rarely, if ever, different from 1.0. The method used to quantity the condition coefficient for highways in the data base is based on delay caused by physical characteristics of the route. It is an artificial lengthening of a route to reflect differences in the quality of the links.

8. Mode Speed.

a. The operating speed on each mode is used in ETNAM to calculate link traversal time, used in the minimum time solution type.

b. Speed may vary on the separate modes, particularly on highways in the several methods of capacity estimation, but ETNAM only accepts a single speed per mode. If, in a given network, there are some routes with one speed and other routes in the same mode with a different speed, it will be necessary for the planner to designate two separate modes, each with its own unique speed.

c. In the absence of information to the contrary, doctrine designates the following speeds:

(1) Inland waterways, 8 knots in open water interpreted as 4 knots upstream against a 4-knot current (12 knots downstream).

(2) Rail, 10 miles in the hour. (Much higher speeds are recorded in Janes World Railways).

(3) Pipeline, not designated specifically but velocity up to 5 feet per second (0.34 miles per hour).

(4) Highways, 35 miles per hour on primary roads and 25 mph on secondary roads. (The Highway Research Board observed higher speeds for different "levels of service" in CONUS, and RAC observed truck speeds of 50 mph on primary roads in Central Europe.)

(5) Air, speeds vary by type aircraft.

9. Transfer Points (Transshipment Points).

a. A potential transfer point exists at any node where two or more modes intersect. In the lists of nodes furnished in the country annexes, each node of this type is identified with the modes intersecting at that node by appropriate suffix symbols, so that the user may make a selection of the transfer points desired for the problem.

b. To select a transfer point requires the introduction of a new link or links as illustrated below. At ports or other origins there may be a multiplicity of mode intersections and several types of transfer may be desired.

c. For example, at a seaport such as Rotterdam (N001 - Netherlands node number 1) there may be highway, rail, IWW, and pipeline links, and a co-located airfield accessible only by highway from the seaport. In addition some of the materiel may be used in the immediate area. The links of this port complex are:

N001S - N001D (seaport to local storage depot)

N001S - N001H (seaport to highway)

N001S - N001R (seaport to rail)

N001S - N001P (seaport to pipeline)

N001S - N001W (seaport to inland waterway)

N001H - N001A (highway to airfield)

N001H - H001R (highway to rail)

d. There are several other possible links, e.g., N001S - N001A, which may be used for helicopter discharge of ships.

10. Origins. The interfaces between intertheater and intratheater transportation systems are represented by that portion of intertheater input to seaports and airfields that becomes input to the intratheater system. Seaports and airfields are normally origins, but forward airfields may also be intertheater destinations. Origins are always paired with one or more destinations.

11. Destinations.

a. The location of destinations is problem-oriented and is not part of the data base. However, for the present situations and where known, the locations of existing depots and storage points are shown on the network maps for each country. Other destinations used in Europe at the present writing are given in the European Theater Transportation System (ETTS) 1969, DCA Control Number 292345, obtainable from the Defense Documentation Center.

b. In establishing destinations for specific problems it is necessary to determine the phased requirements for men and materiel at each, and to estimate the materials handling resources required to receive, store, and issue the incoming materiel. All destinations are paired with one or more origins.

12. Transportation Resources. Transportation resources may be presented as the men-equipment combinations that actually handle or move the commodities (including passengers), and control the movements (including documentation). They are presented as TOE units with given capabilities, functional components that consist of single units manned directly (e.g., forklift truck with operator) or indirectly (e.g., boxcar), and host nation capabilities (e.g., capability of a stevedor crew).

13. Master Resource Vectors. The link resource requirements are assigned by mode-commodity pair; e.g., a single master resource vector[2] is established for each mobility mode and commodity. Thus a single master vector provides the resource data for all links of a particular mode, for all movements of the specified commodity. For example, for POL as a commodity there is a POL/highway master vector which expressed the mobility resources required to sustain a unit flow of POL over a unit distance by highway. Likewise a master vector can be defined for POL/rail.

14. Resource Inventories.

a. The quantity of each allocatable resource available is a necessary data element. This may be the actual or planned inventory of these

[2]A vector is simply a list of numbers each corresponding to a specific resource type. Thus for a given mode-commodity pair there may be several types of resources required.

resources or may be some other figure established by the user as the upper limit of resources to be allocated. In the max flow mode, the quantity of resources available will often be the limiting factor. In the min cost mode, it may be desirable for some analytical purposes to set available resources at high levels so as to permit the system to select the best set of resources regardless of current inventory levels. Thus the quantities to be input as resource inventories will vary widely depending on the analyst's purpose.

b. Total military inventories are problem-oriented and are subject to considerable variation. The composition and capabilities of the military units are prescribed and are furnished in the mode chapters, Part One. The latest inventories of host nations are furnished in the appropriate chapters, Part Two. The entire host nation inventory will probably never be made available to US forces; however, the size of the inventory may indicate a reasonable support level that could be provided by the host nation should it be necessary.

15. Resource Costs.

a. Resource prices, as used in the ETNAM system, reflect value judgments of preferences for use of the allocatable resources. These prices are not necessarily the operating cost of the resources in the theater, but may be a life cycle cost or any other relative index.

b. Prices are required simply because the various resources are not of equal value. If barges and trucks are priced equally, barges with their large capacity will be used to the limit of their ability, consistent with the constraints of the network. The vehicle with the greatest capacity would appear to be the best choice in every case. With a relative price assigned each resource type, for a minimum cost solution type the allocation will be based on economic advantages.

c. Unfortunately, reliable resource cost data for the ETNAM data base are either not readily available or have not been validated. Rather than risk misleading the user inadvertently, it was deemed the better policy not to enter cost data in the data base. If the min cost solution is desired by the user, it will be necessary for him to obtain cost data directly from the Services.

16. Resource Productivity.

a. Transportation resources are defined as the combination of labor, equipment and available facilities for the transport and handling of cargo or passengers (PAX) while enroute from an origin to a destination. Facilities and infrastructure are discussed in terms of capacity as in a previous section. The man-machine combinations are discussed in terms of capability or average productivity.

b. The productivity of any transportation resource unit normally varies daily because of certain, not necessarily predictable, combinations

of circumstances. However, over a long period the average productivity should approach the capability about which the resource unit was designed. The circumstances may include all favorable or unfavorable factors, generally defying quantification, that can possibly arise in the movement of cargo -- momentary or lasting, sporadic or steady.

c. Probably the predominant factor affecting productivity, with respect to tonnage output, lies in the type of commodities handled or transported, particularly if the originating intertheater carrier should happen to be commodity loaded.[3]

d. To illustrate, Army general cargo[4] is shown in the accompanying Table 1 to have a density of 27.8 lbs/cu. ft. (This is the general basis for the determination of certain resource capabilities.) The Terminal Service Co. has a capability (estimated average productivity) of discharging 720 STONS/day and at the above density this equates to a theoretical 52000 cu. ft./day (720 STONS x 2000 lbs divided by 27.8). All other things being equal, and assuming circumstances favorable to the operation, the daily productivity of this unit can vary theoretically from 1675 STONS of army ammunition (50 lb/cu. ft.) to 31 STONS of army aircraft (0.93 lbs/cu. ft.) if only the single commodity is discharged. Zero productivity days, when there is no ship in port, or operations are suspended, are deliberately ignored for the purpose of the illustration. The daily productivity of the connecting intratheater carriers would be similarly affected if both commodities could be moved by the same carriers.

e. Resource capabilities are compared with the estimated workloads to obtain resource requirements. Chapters 4 to 9 include design capabilities and type resource requirement computations.

[3] See types of loadings in FM 55-15 or FM 101-10-1.

[4] Measurement tons.

TABLE 1. CARGO DENSITY PLANNING FACTORS

Supply class	Commodity	MTON[3] per STON	Lbs/cu.ft.
Cl I	Reefer	1.86	26.9–27.5
	Chill	2.1	23.8
	Freeze	1.0	50.0
	Other	2.2	23.8–33.5
Cl II	Clothing and Textiles	3.5	14.3–17.5
Cl III	Packaged	1.25	40.0
	Bulk	1.04	48.2
Cl IV	Materials	2.4	20.8
Cl V	Gen'l (Mixed)	1.25	40.0–46.5
	Army	1.0	50.0
	Navy	1.07	46.7
	USAF	1.54	32.4
	USMC	.97	51.5
Cl VI, X	Exchange		
	Wartime	2.13	23.4
	Peace	1.96	25.5
Cl VII	Aircraft (Gen'l)	53.7	0.93
	C-1A	18.0	2.78
	C-6A	32.0	1.56
	C-5D	72.5	0.69
	OH-13	70.0	0.72
	CH-23	52.0	0.96
	UH-1B	37.0	1.35
	UH-1D	69.0	0.73
	UH-19	65.0	0.77
	CH-21	78.0	0.64
	CH-34	52.2	0.96
	CH-37	58.0	0.86
	CH-47	30.0	1.67
	Construction Equipment		
	Navy	2.1	23.8
	Army	1.5	33.3
	Special[5]	4.73	10.6
	Transportation Equipment		
	Army	8.0	6.3
	Navy	5.54	9.0
Cl X	Aid	1.3	38.4
	MAP	1.5	33.3
No class	Balloon Cargo (Empties)	3.22	15.5
	Bulk Commodities	1.21	41.5
	Cargo Carrying Trailers	5.21	9.6
	Containerized Cargo	2.27	22.0
	Gen'l Stores (Navy)	1.42	35.2
	Gen'l Cargo (Army)	1.8	27.8
	Gen'l Less HHG - Gen'l Cargo	2.32	21.5
	HHG	8.1	6.2
	POV	7.54	6.63

TABLE 1. CARGO DENSITY PLANNING FACTORS ([illegible])

Supply class	Commodity	MTONS[a] per STON	Lbs. cu. ft.
	Special Projects	1.5	33.3
	Unit Equipment	4.2	11.[illegible]
	Weighted Average	2.6	1[illegible].2
	Weighted Average less [illegible]	[illegible]	21.6

[a] Measurement Tons

[b] Mostly wheeled and tracked military vehicles, weighing more than [illegible] STONS and measuring more than [illegible] feet in any dimension.

Sources:

Traffic Management Handbook, USATMACS, Jan [illegible].

[illegible] TDC-1, Logistics Strategic Mobility Planning, 15 Mar [illegible]

RAC-R-[illegible], An Evaluation of a Heavy-Lift Helicopter in the Logistical Role, Aug [illegible].

CHAPTER 4. HIGHWAY

1. Highway Capacity Estimations.

a. The Army method of highway capacity estimation, hereinafter called the "current" method, is contained in FM 55-15 and FM 101-10-1. It is a condensed version of the more complicated method given in FM 55-54, which it supersedes. The current method was used in deriving the capacity estimates for the European data base, in spite of its almost unanimous rejection by the participants in the 1968 seminar on this subject, hosted by the Engineer Strategic Studies Group at the National Bureau of Standards. However, at the moment it enjoys official sanction by the Army and for this reason was the natural choice.

b. The literature is replete with papers on the subject, but the theory of traffic flow has not yet produced a single methodology acceptable to all concerned. Proponents of various methods freely admit that much more experimentation and validation is necessary before such methodology can be developed.

c. A number of these methods are discussed in this chapter, not only to afford the planner a selection, but to illustrate the more prominent approaches to capacity estimation, and to compare the results obtained from each as closely as possible.

d. Closely related to the current method are the NATO method and the proposed DIA method. The NATO methodology was used in developing the FM 55-54 methodology and is still used, at this writing, by the Defense Intelligence Agency (DIA). The DIA proposal (still under review) contains some new features and permits a great deal of subjectivity in selecting factor values -- the common fault of most methods. Generally, these factors are multiplicative such that minor differences in factor values, even in the same method, can give unacceptedly divergent results.

e. In addition to the current method, a "quick" method presented in FM 55-15, for use when very little data are available, is discussed.

f. The convoy method, used principally for unit moves but available for large logistic movements, is also discussed. The convoy is a highly regulated movement and places more emphasis on control rather than cargo lift. European regulations were used instead of the more general regulations in FM 55-15 and FM 101-10-1.

g. The Highway Research Board has developed a method which is based on extensive study of passenger cars moving on sophisticated roads and evaluates potential truck volume on the basis of passenger car equivalents (pce).

h. Finally, a method developed by RAND is presented. This is based on a limited experimentation with trucks on the secondary and tertiary

roads in Asia. Comparison of the RAND method with others is difficult because of lesser permissible speeds and great gaps between vehicles because of dust.

i. The RAC study team, in compiling the European Theater Transportation System (ETTS), traveled in excess of 3000 miles in Europe on autobahns and other primary roads, measuring traffic flow and the salient features of the roads and the traffic using them. The findings of this study pertaining to highway traffic are presented for consideration and, although no method is proposed as such, the significant influence of some physical and operational characteristics on capacity emerge in the derivation of a "condition coefficient," one of the important elements of ETNAM.

j. Finally, the military transportation resource capabilities and sample productivities are discussed. Host nation transportation resources are always included in the chapter pertaining to a specific country.

k. In comparing the results of the various methods for highway capacity estimation, a single hypothetical highway was chosen to which each of the methods was applied. The hypothetical road has the characteristics described below. It will be noted that some characteristics are considered necessary in one method but completely ignored in another. The evidence strongly indicates that the quantitative influence of certain characteristics has not been ascertained accurately or satisfactorily.

l. The road connects origin A with destination B and has the following physical and operational characteristics:

Length:	103 miles
Road type:	Bituminous concrete, type 2, 7" sub-base, 4" base, 4" pavement
Location:	COMMZ
Width:	Narrow, 20 feet wide, 10 feet lanes undivided
Use:	Sustained, operation (20 hours/day)
Vehicle type:	5 ton
Vehicle load:	3.5 STONS average for all trucks
Shoulder width:	Varies 2-9 feet
Ruling gradients (terrain):	5% to 7%, hilly
Curvature:	All radii greater than 500 ft.

Condition:	Dry
Bridges:	All adequate capacity
Engress/ingress loss:	15% (factor of 0.85)
Maintenance:	(Factor of 1.00)
Speed Average:	35 mph (except as noted), 20mph in cities
Cities:	Origin is 5 miles within city A Destination is 1 mile within city B
Towns:	5, averaging 1 mile in length
Controlled isolated intersections	3 near city A (2 minutes alternating traffic signals)
	1 rail crossing near city B (- times daily, 5 minutes delay each)
City intersections:	5 per mile
Speedometer multiplier:	1

m. Certain special assumptions are included in the sample computations as required.

n. Capacities are obtained in vehicles per lane per day and the equivalent tonnage comparison may be obtained by multiplying the number of vehicles by the average payload per vehicle. The tonnage capacity is a user option and is a function of the vehicle payload that may vary considerably, as shown on Table 2.

o. The basic vehicle used in the computations to obtain maximum capacity in vehicles per day (vpd) was the 5-ton truck. Adjustments to the vpd to obtain equivalent numbers of other type vehicles, obtained from FM 55-54 are as follows: When using 10-12 ton trucks the vpd is 95 percent of the number of basic vehicles, for 18-20 ton trucks only 80 percent, and for 20+ tons only 59 percent.

p. A summary of the results of each method in estimating capacity of the specimen road shows:

Method	Vehicles per day (vpd)
FM 55-15 (current)	2520
NATO	3050
DIA (proposed)	3030

TABLE 2. VEHICLE PAYLOADS

Vehicle Description	Loading	Payload (STONS)
3-axle truck	Average	3.5 [1]
3-axle truck	Rated	5.0 [1]
3-axle truck	Maximum	10.0 [1]
Med.Trk-Trctr,Semitrlr	Average	7.0 [1]
Med.Trk-Trctr,Semitrlr	Rated	10.0 [1]
Hvy Trk-Trctr,Semitrlr	Average	12.0 [1]
Hvy Trk-Trctr,Semitrlr	Av. Ammo	14.0 [1]
Hvy Trk-Trctr,Semitrlr	Maximum	18.0 [1]
All types Mix Benelux & FRG	(Sample 2200 military veh trips for one year)	8.5
20' Container, Trk [2] or Commercial Vehicles	Max UK Max Portugal & Med. Countries	21.0 19.0
40' Container, Trk [2] or Commercial Vehicles w/trlr	Max FRG & Spain Max BENELUX	28.0 30.0
20' Container, Trk w/trlr or Commercial Vehicles w/trlr	Max Netherlands	40.0

1 Derived from FM 55-54 and FM 55-15 for type vehicle payloads.

2 The tare weight of the containers is assumed to average 6500 lbs.
20' x 8' x 8' containers range from 3100 to 5080 lbs, median 4400 lbs
40' x 8' x 8' containers range from 5630 to 7937 lbs, median 6350 lbs
40' x 8' x 8½' containers range from 7275 to 8500 lbs, median 7700 lbs

Method	Vehicles per day (vpd)
FM 55-15 (quick)	2360
CONVOY	1070
Highway Research Board	6480
RAND	1216

For the given road, based on RAC findings on European roads, the capacity is of the following order:

SM = 1[3]	17100 vpd
SM = 4[3]	5550 vpd

2. Road Classification. Since the type of road plays an important part in capacity estimation it is considered advisable to preface the discussion of estimation methodologies with definitions and characteristics of the type roads that will be considered.

a. Type 1. Cement Concrete (Waterproof). 7"-12" monolithic, reinforced slabs with lateral and longitudinal joints. Edge is regular and well defined. Older roads may be laid directly on subbase, but modern roads have a granular base. Capable of taking maximum logistic loads for extended periods. Common causes of failure are "pumping" (poor base materials -- vehicle movement forces water and fine particles from beneath the pavement) and "scaling" (areas of severe frost -- improper mixing and segregatio[illegible] creates scaling spots).

b. Type 2. Bituminous Concrete (Waterproof). 3"-6" surface in two courses (wearing surface is fine aggregate and the lower course aggregate, both mixed with bitumen) on a 8"-12" granular base. Older roads had 3"-5" surface and 5"-10" base, with some periodic resurfacing. Regular edge but not as sharp as cement concrete. Common failures are pot holes and surface ravelling caused by subgrade failure, inadequate base, deteriorated surface bond, improper mix, or poor materials. The wearing course tends to displace under heavy traffic to form a transverse corrugation. Lower type surfaces that have had repeated surface treatments or have an exceptionally thick, well-drained base course are placed in this class.

c. Type 3. Stone Block (Waterproof). Block on a sand or asphalt mat on macadam base. The older block roads with a sturdier foundation, and grouted blocks, are not as susceptible to failure. These pavements tend to become uneven and present a rough rid[illegible] and slippery surface.

d. Type 4. Road Mix and Penetration Bituminous (Intermediate) Waterproof). These are mixed in place and laid by a paving machine. Wearing cours[illegible] is 1½"-3", on a 5"-6" waterbound macadam base. Ragged.

[3] SM = Speedometer Multiplier, a number used to multiply the speedometer reading to obtain the gap distance between vehicles in yards, i.e., 50 (mph) x (SM = 3) = 150 yards.

ill-defined edges. Under heavy traffic tends to fail by ravelling at the edges and forming pot holes. Disfigurement often appears in the form of logitudinal ridges and transverse corrugations.

e. Type 5. Bituminous Surface Treatment (Waterproof). Depth varies according to type of bituminous material, method of application, type of aggregate, and number of additional treatments. Irregular, ragged edges. Normally many patches were ravelling and pot holes have been repaired. Weak because no effort is usually made to improve the subgrade.

f. Type 6. Traffic-bound Macadam or Gravel (Metalled). Compacted gravel and crushed rock. Successive layers of decreasingly sized stone, usually with a clayed binder. Fails by dusting, and spalling of larger size material. With optimum moisture content these are excellent roads.

g. Type 7. Improved Earth. Natural ground with minor improvement such as provision for drainage. May become impassible in wet weather.

h. Type 8. Unimproved Earth. Usually only a track on natural ground, impassible in wet weather.

(1) Sand and gravel. Quick-draining and nonplastic. Provides satisfactory all-weather surface when moist. Generally must have a clayey admixture.

(2) Clay. Varies greatly under different moisture conditions. With optimum moisture it is a good surface. Prone to pulverize and dust under dry conditions.

(3) Silts. Extremely unstable unless mixed with other soils. Deforms in wet weather.

(4) Frozen surface. Practically all earth roads can support heavy traffic during the freeze period.

3. FM 55-15 Methodology (Current Method).

a. This is the current doctrinal method used in estimating highway capacity that was used for the highway data base of ETRAM for Europe. The capacities given in intelligence documents were presumably computed by this method and were extracted from these documents for all other countries in the data base. The predecessor to this method was the more detailed FM 55-54, by no means obsolete but superseded by the condensed FM 55-15 version.

b. The FM 55-15 method combines capacity and capability factors in arriving at a capacity expressed in STONS/day. The method starts with several vehicle type classes. Using a fixed gap between vehicles and a fixed speed, the "basic" or maximum capacity in vehicles per 24 hour day

(2-lane, both directions) is obtained for each vehicle class. The "operational capacity" is then taken as 80 percent of the basic capacity, as shown in Table 3. The derivation of the 80 percent factor is not clear, but presumably it is introduced to take care of such things as driver fatigue, driving conditions, adverse weather, random dispatch, and other conditions not specifically evaluated by other factors.

c. The operational capacity is for ideal conditions and is subsequently degraded for practical use by the effect of quantifiable operational considerations and physical characteristics of the road.

d. The first reduction is for hours of operation. The capacity values given in Table 3 are for 24-hour continuous use and this is multiplied by 0.83 for 20-hour operation (2 shift) or by 0.50 for 12-hour operation (1 shift).

e. The second reduction is for egress, ingress, and cross movements losses, estimated generally as 15 percent or a factor of 0.85. More detailed analysis of a specific road may indicate a higher or lower reduction.

f. The next reduction is to divide by the number of lanes to get flow per lane.

g. A series of reductions are generated by the physical characteristics of the road. In random order the factor tables are: alinement (Table 4), base thickness (Table 5), surface and shoulder widths (Table 6), and maintenance (Table 7).

h. As an update, the factors for the most commonly used logistic vehicles in the US Army today have been interpolated as shown in Table 8, and are used to form the factor tables.

i. The major disadvantages of the FM 55-15 method derived from FM 55-54 are: (1) the factor values cannot be substantiated, (2) factor interaction is ignored and results in a more severe degradation than required, and (3) the vehicles used to obtain tonnage capacities are not in the Army inventory (with one possible exception). FM 55-54 frankly states "that much basic information was lacking" and implies that many of the factor values were actually opinions. To avoid the necessity for interpolation of truck payloads, planners have been instructed by the intelligence community to take average truck payloads in sophisticated countries as 7 STONS and in lesser countries as 5 STONS. Unfortunately the factor values, originally intended as guides only, tend to be locked in when capacities computed from them are published in official documents.

j. The following is an example of the use of the FM 55-15 method in estimating capacity. Slide rule accuracy is sufficient.

TABLE 3. HIGHWAY DAILY CAPACITY (FM 55-15)

Surface type	Vehicle type	Average Speed (mph)	Vehicle Interval (ft)	24 hour capacity both directions Vehicles	
				Basic[4]	Operational[5]
1,2,3,4,5	Gp 1	25	300	21000	16900
	Gp 2	25	325	19200	15400
	Gp 3	20	400	12500	10000
6	Gp 1	20	600	8400	6700
	Gp 2	20	700	7700	6200
	Gp 3	15	700	5800	4600
7	Gp 1	20	800	6300	5000
	Gp 2	20	800	6300	5000
	Gp 3	15	800	5000	4000
8	Gp 1	15	1000	3800	3000
	Gp 2	10	1000	2500	2000
	Gp 3	10	1000	2500	2000

Group 1 $2\frac{1}{2}$ ton
5 ton
1000 gal

Group 2 10 ton
5000 gal semi
12 ton S&T semi

Group 3 25 ton low bed
50 ton low bed

[4] Basic: All factors = 1.0

[5] Operational: 80% of basic

Note: For 20 hour capacity multiply vehicles by 0.83. For 12 hour capacity multiply by 0.50.

TABLE 4. CURVE AND GRADIENT FACTORS AND GROSS VEHICLE WEIGHT (FM 55-15)

Ruling Alinement*		3 - Axle				Combinations		
Curve Radius (ft)	Gradient	2½ T	5T	10T	1200 gal Tanker	5000 gal Tanker w/ trctr	12T S&T semi w/trctr	28T semi lo-bed w/ trctr
<50	>11	0.40	0.40	0.20	0.40	0.20	0.20	0.20
50	11	0.40	0.40	0.20	0.40	0.20	0.20	0.20
62.5	10	0.50	0.51	0.29	0.50	0.29	0.29	0.23
75	9	0.60	0.63	0.38	0.60	0.38	0.38	0.27
87.5	8	0.70	0.71	0.44	0.70	0.44	0.44	0.31
100	7	0.75	0.78	0.50	0.75	0.50	0.50	0.35
112.5	6.5	0.78	0.83	0.55	0.78	0.55	0.55	0.40
125	6	0.82	0.88	0.61	0.82	0.61	0.61	0.46
137.5	5.5	0.85	0.91	0.66	0.85	0.66	0.66	0.52
150	5	0.88	0.94	0.71	0.88	0.71	0.71	0.57
162.5	4.75	0.90	0.96	0.75	0.90	0.75	0.75	0.62
175	4.5	0.92	0.98	0.78	0.92	0.78	0.78	0.67
187.5	4.25	0.94	0.99	0.82	0.94	0.82	0.82	0.71
200	4	0.95	0.99	0.86	0.95	0.86	0.86	0.75
212.5	3.75	0.97	1.00	0.88	0.97	0.88	0.88	0.78
225	3.5	0.98	1.00	0.91	0.98	0.91	0.91	0.81
237.5	3.25	0.98	1.00	0.93	0.98	0.93	0.93	0.83
250	3	0.99	1.00	0.95	0.99	0.95	0.95	0.86
262.5	2.875	0.99	1.00	0.96	0.99	0.96	0.96	0.87
275	2.75	1.00	1.00	0.98	1.00	0.98	0.98	0.89
287.5	2.625	1.00	1.00	0.98	1.00	0.98	0.98	0.91
300	2.5	1.00	1.00	0.99	1.00	0.99	0.99	0.93
312.5	2.375	1.00	1.00	0.99	1.00	0.99	0.99	0.94
325	2.25	1.00	1.00	1.00	1.00	1.00	1.00	0.95
337.5	2.125	1.00	1.00	1.00	1.00	1.00	1.00	0.96
350	2	1.00	1.00	1.00	1.00	1.00	1.00	0.98
>350	<2	1.00	1.00	1.00	1.00	1.00	1.00	

* Apply only factor that gives minimum capacity

Gross Weight (STONS)	2½ T	5T	10T	1200 gal Tanker	5000 gal Tanker w/ trctr	12T S&T semi w/trctr	28T semi lo-bed w/ trctr
Empty	6.5	10.5	17	7	7.5	7	17
X Country	9.0	15.5	27	10	17.0	19	--
On Road	11.5	20.5	32	11	23.0	25	42
Av. Payload (STONS)	2.2	3.5	7	3	14	10	NA

TABLE 5. BASE THICKNESS FACTORS (FM 55-15)

Surface Type	Base Thickness (ins) 1	2	3	4	5	6	7	8	9	10
1,2	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
3	0.13	0.26	0.38	0.49	0.62	0.75	0.88	1.0		
4,5	0.2	0.35	0.5	0.65	0.83	1.0				
6	0.3	0.52	0.79	1.0						

TABLE 6. SURFACE AND SHOULDER WIDTH FACTORS (FM 55-15)

Type of Movement	No. of Lanes	Both Known: Surface Width (ft)	Both Known: Surface Divided Highway	Both Known: Surface Undivided Highway	Both Known: Shoulder Width (ft)	Both Known: Shoulder Divided Highway	Both Known: Shoulder Undivided Highway	Surface Only Known: Width (ft)	Surface Only Known: Movement one-way	Surface Only Known: Movement two-way
One-way	1	8		0.44	0		0.74	8	0.33	
	1	9		0.51	1		0.79	10	0.39	
	1	10		0.58	2		0.85	12	0.45	
	1	11		0.64	3		0.93	14	0.47	
	1	12		0.68	4		0.97	16	0.53	
	1	12-18*		0.68	5		0.98	18	0.58	
	1	>18		**	6		0.99	20	0.675	
	1				7		1.00	22	0.675	
	1				>7		1.00			
Two-way	2	18		0.75	0		0.70	18		0.58
	2	19		0.80	1		0.75	20		0.575
	2	20		0.85	2		0.80	22		0.63
	2	21		0.90	3		0.85	24		0.68
	2	22		0.95	4		0.90	26		0.73
	2	23		0.98	5		0.94	28		0.77
	2-3	24		1.00	6		0.97	30		0.80
	2-3	24-35		1.00	7		0.98	32		0.835
	2-3	>35		1.00	8		0.98	34		0.85
	2-3				9		0.99	36		0.77
	2-3				10		0.99	38		0.87
	2-3				11		0.99	40		0.87
	2-3				12		1.00	42		0.88
	2-3				>12		1.00	44		[illegible]
	4	36	2.0	1.8	0-2	0.80	0.80	46		0.96
	4	42	2.2	2.0	2-7	0.90	0.90	48		1.00
	4	48	2.5	2.2	7-12	1.00	1.00	50		1.00
	4				>12	1.00	1.00			

*Width between 12' and 18' take ½ width over 12' as additional shoulder

**Use half actual width as surface within table, then double result to reflect two lines of traffic

TABLE 7. MAINTENANCE FACTORS (FM 55-15)

Surface Type	Veh Type	Sand/Gravel Dry	Sand/Gravel Moist	Sand/Gravel Wet	Sand/Gravel Frozen	Clay Dry	Clay Moist	Clay Wet	Clay Frozen	Silt Dry	Silt Moist	Silt Wet	Silt Frozen
1,2,3	Op 1	1.00	1.00	0.95	1.00	1.00	1.00	0.80	1.00				
	Op 2	0.90	0.90	0.90	1.00	0.90	0.90	0.40	1.00				
	Op 3	0.90	0.90	0.85	1.00	0.90	0.60	0.70	1.00				
	Crash Days	30	30	20	*	30	30	15	*				
4	Op 1	0.90	0.90	0.80	1.00	0.90	0.90	0.55	1.00				
	Op 2	0.80	0.80	0.70	1.00	0.80	0.80	0.44	1.00				
	Op 3	0.80	0.80	0.60	1.00	0.80	0.80	0.45	1.00				
	Crash Days	15	15	4	*	15	15	2	*				
5	Op 1	0.40	0.50	0.30	1.00	0.40	0.50	0.25	1.00	0.25	0.25	0	1.00
	Op 2	0.30	0.35	0.20	1.00	0.30	0.35	0.15	1.00	0.15	0.15	0	1.00
	Op 3	0.25	0.30	0.15	1.00	0.25	0.30	0.10	1.00	0.10	0.10	0	1.00
	Crash Days	10	10	3	4	10	10	1	*	2	2	0	*
6	Op 1	0.25	0.35	0.15	0.35	0.25	0.45	0.15	1.00	0.15	0.15	0	1.00
	Op 2	0.20	0.30	0.10	0.30	0.20	0.30	0.05	1.00	0.10	0.10	0	1.00
	Op 3	0.10	0.25	0.05	0.25	0.10	0.25	0.05	1.00	0.05	0.05	0	1.00
	Crash Days	5	5	[illegible]	*	5	5	[illegible]	*	[illegible]	[illegible]	0	*
7	Op 1	0.25	0.35	0.15	0.35	0.35	0.70	0	1.00	0.05	0.05	0	1.00
	Op 2	0.20	0.30	0.10	0.30	0.20	0.45	0	1.00	0	0	0	1.00
	Op 3	0.10	0.25	0.05	0.25	0.20	0.45	0	1.00	0	0	0	1.00
	Crash Days	5	5	0	*	5	5	0	*	[illegible]	[illegible]	0	*
8	Op 1	0.25	0.25	0.10	0.25	0.35	0.60	0	2.00	0.05	0.05	0	2.00
	Op 2	0.20	0.20	0.05	0.20	0.25	0.35	0	2.00	0	0	0	2.00
	Op 3	0.10	0.20	0	0.20	0.20	0.35	0	2.00	0	0	0	2.00
	Crash Days	5	5	0	*	5	5	0	*	0	0	0	*

*Frozen soil can accommodate crash movements for the duration of the freeze.
Crash days are maximum number of days basic capacity can be used.

Op 1 2 axle trucks up to 5T
Op 2 Medium semitrailers
Op 3 Heavy wheeled vehicles

SURFACE TYPE

1 Cement Concrete
2 Bituminous Concrete
3 Block
4 Road Mix/Penetration
5 Bituminous Surface Treatment
6 Gravel/Traffic bound Macadam
7 Improved Earth
8 Unimproved Earth

Example: Evaluate the capacity of the previously defined hypothetical highway between A and B.

Table 3 gives 16400 vpd for this surface type and vehicle type. Applying the relevant factor values:

20 hour day	16400 x 0.85 = 14000
Egress/ingress loss	14000 x 0.85 = 11900
Per lane	11900 x .50 = 5950 vehs/lane/day
Alinement (Table 4), 7% gradient	5950 x 0.78 = 4640 vehs/lane/day
Base thickness, 8" (Table 5)	4640 x 0.8 = 3720 vehs/lane/day
Paved Width 20' (Table 6)	3720 x 0.85 = 3160 vehs/lane/day
Shoulder Width, 2' min (Table 6)	3160 x 0.80 = 2520 vehs/lane/day
Maintenance (Table 7)	2520 x 1.00 = 2520 vehs/lane/day
Capacity	= 2520 vehicles (5 ton)/lane/20 hr day

4. <u>BATC Method.</u>

a. The BATC method (agreed US/UK Road Capacity Methodology, 1961) is very similar to the FM 55-15 method with the same disadvantages but differs from that method by considering only the 5-ton vehicle (Group 1 vehicles). However, many of the factor values are different, the base thickness factors are ignored, and there are other minor points of dissimilarity. This method uses 0.85 for egress/ingress loss, 0.50 for sustained operation, and 0.85 for short term (crash). Capacity by this method for the same highway conditions is 3050 vehs/lane/day.

5. <u>DIA Method.</u>

a. DIA has proposed a new methodology, currently being evaluated. This method is a proposed modification of current methodology, and contains some important quantitative assumptions that will require verification by field experimentation. While oriented toward intelligence estimates, it contains elements that are considered in highway capacity estimation for strategic movement planning.

b. As with most other methods it starts with a computation of "basic" capacity, i.e., saturation of the ideal road under specific operational conditions, for a 24-hour time period. Basic capacity is then attenuated by factors related to physical and operational characteristics of specific routes. Qualitative influences on movement are to be quantified by judgment.

c. Basic capacities for this method are fixed. Values for average speeds and the fixed vehicle intervals were obtained by judgment only. Basic capacities are computed from the formula:

$$\text{vpd per lane} = \frac{5280}{\text{interval}} \times \text{speed} \times 24 \text{ hours}$$

d. Reductions in basic capacity start with the application of a combined surface and shoulder width factor. Alinement factors further reduce basic capacity. Maintenance factors are based on the effect of repeated axle loads of a $2\frac{1}{2}$-ton truck with a 4 ton payload. The turning and cross movement factor of 0.85 is suggested as a guide intended to impart realism to the estimate.

e. An operational efficiency factor is introduced, the application of which is entirely judgmental. As a guide to planners the following values are suggested:

1.0 optimum
.9
.8 norm
.7
.6
.5 or below inefficient

f. These values are based on such considerations as doctrine, logistical planning and management, training, experience, and driver characteristics.

g. The halt factor to be applied is assumed as a constant 0.8. Judgment is required in applying a weather factor such that the same effect is not applied more than once. The index truck is the $2\frac{1}{2}$-ton with average 4-STON payload. Capacity by this method at norm on the same highway conditions is 3030 veh/lane/day.

6. Quick Estimation Method (FM 55-15).

a. This method is only to be used when information necessary for more detailed estimation is lacking. It is best described by the tabulation in Table 8. Speed factors are not given for this method.

TABLE 5. FACTORS FOR QUICK ESTIMATION

Road type	Daily tonnage forward				Reduction factors			
	Optimum dispatch (STONS)	COMMZ traffic (STONS)	CZ traffic (STONS)	Narrow road	Terrain rolling	Terrain hilly	Terrain mount	Adverse seasonal* weather
1	60000	36000	8400	0.75	0.90	0.70	0.40	0.80
2,3,4	45000	<u>27000</u>	7300	<u>0.75</u>	0.90	<u>0.70</u>	0.40	<u>0.70</u>
5	30000	18000	5800	0.75	0.80	0.60	0.35	0.60
6	10150	6090	3400	0.75	0.60	0.50	0.30	0.40
7,8	3300	2240	1600	0.75	0.75	0.40	0.20	0.10

*Used only for sustained operations.

b. Example: Capacity of the hypothetical highway between A and B, under sustained operation with average payloads of 3.5 STONS.

Tonnage: COMMZ traffic
27000 x 0.75 x 0.70 x 0.70 x .83 (to reduce to 20 hours) = 8265 STONS/lane/20 hour day

$\frac{8265}{3.5}$ = 2360 vpd/lane

7. <u>Convoy Method</u>. The convoy method is included as a method of highway capacity estimation because its fairly rigid control standardizes the value of the parameters to be used. USAREUR regulations are followed instead of FM 101-10-1 to obtain capacity results of only 1170 vehs/lane/day.

8. <u>Highway Research Board (HRB) Method (Special Report #87, 1965)</u>.

a. The HRB uses a much different approach to the estimation of highway capacity than any other method. It is similar to the other methods in that a maximum capacity, obtained from tabular values, is degraded by certain operational aspects and the physical characteristics of the road, but there the resemblance ends. It is based on the performance of passenger cars, and the number of passenger cars per hour (pcph) is used as the basic measurement. The equivalent number of trucks, under varying conditions, is computed from tabular values of "passenger car equivalents (PCE)". For an understanding of the method it is necessary to be aware of the fact that the HRB method admits the significant effect of certain physical characteristics acting to reduce the theoretical maximum, but makes no attempt to

quantify these effects. These characteristics are discussed as separate entities, indicating the disposition proposed for each. Those factors not quantified are not applied to the example given to illustrate the method.

b. In order to describe the HRB method it is necessary to define the terms used and to discuss the treatment accorded road and traffic characteristics.

c. <u>Level of Service.</u> Of major importance in the concept is the measurement of traffic flow in terms of "levels of service" defined as follows:

(1) Level A. A condition of free flow, with low volumes and high speed and no restriction in maneuverability. Associated with freeways and expressways with low traffic volume. Operating speed ≥60 mph.

(2) Level B. The high range of stable flow. Drivers still have reasonable freedom to select speed and lane of operation. The lower limit (lowest speed, highest volume) is associated with the design of rural highways. Operating speed ≥55 mph.

(3) Level C. The midrange of stable flow, with speeds and maneuverability more closely controlled by the higher volumes. Associated with the design of urban roads. Operation speed ≥50 mph.

(4) Level D. The lower range of stable flow, with little freedom to maneuver, and comfort and convenience are low. Operating speed ≥40 mph.

(5) Level E. Unstable flow, with stoppages of momentary duration. The flow approaches saturation. Operating speed 30-35 mph.

(6) Level F. Forced flow. Usually in queues with vehicles backed up. Speeds are low and stoppages occur frequently. Operating speed <30 mph.

d. <u>Maximum Volume, Theoretical and Practical.</u>

(1) The above levels are used in Table 9 to define maximum volumes. In this table the operating speeds of the service levels for four types of highways are used for the ordinate scale, and the maximum speed restrictions for the road are used to form the abscissa. The theoretical maximum volume of pcph are tabulated for each condition, provided it is possible for the condition to exist. The theoretical maximum volume (capacity) is taken as 2000 pcph per lane (Level E) for all roads. When the traffic volume equals capacity operating conditions are poor even under otherwise ideal conditions.

TABLE 9. THEORETICAL MAXIMUM VOLUME (PASSENGER CARS PER HOUR) (PCPH)

Freeways

Level	Operating Speed	Per lane: Speed Restriction 70mph	60mph	50mph	Each add. lane over 2
A	≥60	700	--	--	1000
B	≥55	1000	500	--	1500
C	≥50	1500	900	--	1800
D	≥40	1800	1500	900	1800
E	30-35	2000	2000	2000	2000
F	<30	Variable			

Multilane Rural

Level	Operating Speed	Per lane: 70mph	60mph	50mph	Each add. lane over 2
A	≥60	600	--	--	600
B	≥55	1000	400	--	1000
C	≥45	1500	1000	500	1500
D	≥35	1800	1700	1400	1800
E	30	2000	2000	2000	2000
F	<30	Variable			

2-lane

Level	Operating Speed	Total, both directions: 70mph	60mph	50mph	40mph	35mph	3 lane*
A	≥60	400	--	--	--	--	--
B	≥50	900	800	--	--	--	1500
C	≥40	1400	1320	1120	1020	--	2000
D	≥35	1700	1660	1500	1340	1160	--
E	30	2000	2000	2000	2000	2000	4000
F	<30	Not Meaningful					

*For reversible lane, use multilane factors for direction of flow

Urban and Suburban Arterials

Level	Operating Speed	Per lane: Probable	Near Perfect
A	≥30	1200	1600
B	≥25	1400	1700
C	≥20	1600	1800
D	>15	1800	1900
E	15	2000	--
F	<15	Not meaningful	

(2) Taking the theoretical volume from Table 9 is the first step in the method. For example, on a 2-lane highway with a restricted maximum speed of 50 mph but with an operating speed equal to or greater than 35 mph (Level D) the maximum number of pcph is 1500 total for both directions.

(3) However, to provide an acceptable level of service, volume must be lower than capacity. In the above example, for instance, it would seem advisable to reduce operating speed to 30 mph and thus increase volume to 2000 pcph, but Level E is not considered an acceptable level of service.

(4) In rural areas or on limited access roads travel speed is taken as the operating speed (mph). In urban areas the average overall speed (mih) is used as the operating speed.

(5) To obtain theoretical maximum road capacity in mixed vehicles per hour use the relationship:

$$C = \frac{100\ V\ N\ W}{100 + P_T\ (E_T - 1)}$$ (multiplying by $\frac{100}{100}$ so percent is a whole number)

where
- V = maximum pcph taken from Table 9 for restricted speed and postulated level of service
- C = capacity in mixed vehicles per hour for on direction
- N = number of lanes in one direction
- W = adjustment coefficient from Table 10
- P_T = percent of trucks
- E_T = passenger-car equivalents from Table 11 for the overall estimate.

The maximum number of trucks per hour is obtained by letting

$P_T = 100$

e. Lane Width and Laterial Clearance.

(1) The next step in the method is to consider lane width and lateral clearance and the other pertinent characteristics. Each of these elements affect flow individually, but in practice they are interrelated and Table 10 gives the values for a combined adjustment. The appropriate factor value (W) from the table is used in the formula above. Values not shown may be interpolated. For example, if the lane width is 10 feet on a 2-lane road and there are 4 foot shoulders on both sides of the road, at Level D the interpolated factor is 0.74.

(2) The absence of shoulders (lateral clearance) affects flow of a lane for a short time when blocked by a disabled vehicle. Not

TABLE 10. COMBINED EFFECT OF LANE WIDTH AND LATERAL CLEARANCE

Adjustment Factors

Uninterrupted Flow

Shoulder (ft)	Obstruction on one side (Lane width, ft) 12	11	10	9	Obstructions on both sides (Lane width, ft) 12	11	10	9
Four Lane Divided (2000 pcph per lane)								
6	1.00	.97	.91	.81	1.00	.97	.91	.81
4	0.99	.96	.90	.80	.98	.95	.89	.79
2	0.97	.94	.88	.79	.94	.91	.86	.76
0	0.90	.87	.82	.73	.81	.79	.74	.66
Four Lane Undivided (2000 pcph per lane)								
6	1.00	.95	.89	.77	NA	NA	NA	NA
4	0.98	.94	.88	.76	NA	NA	NA	NA
2	0.95	.92	.86	.75	.94	.91	.86	NA
0	0.88	.85	.80	.70	.81	.79	.74	.66

NA = Not applicable. Use adjustment for one side only.

Two Lane (selected service level)

Shoulder (ft)	Obstruction on one side, Level of Service: 12 B	12 E	11 B	11 E	10 B	10 E	9 B	9 E	Obstructions on both sides, Level of Service: 12 B	12 E	11 B	11 E	10 B	10 E	9 B	9 E
6	1.00	1.00	.86	.88	.77	.81	.70	.76	1.00	1.00	.86	.88	.77	.81	.70	.76
4	.96	.97	.83	.85	.74	.79	.68	.74	.92	.94	.79	.83	.71	.76	.65	.71
2	.91	.93	.78	.81	.70	.75	.64	.70	.81	.85	.70	.75	.63	.69	.57	.65
0	.85	.88	.73	.77	.66	.71	.60	.66	.70	.76	.60	.57	.54	.62	.49	.58

B = Speed ≈ 55 mph 1,000 pcph both ways total

E = Speed ≈ 30 mph 2000 pcph both ways total

only is the lane blocked but the other lanes will be slowed by curious drivers. On the other hand HRB states that a 4 foot shoulder increases the effective width of the adjacent lane by 1 foot.

f. <u>Lane Distribution</u>. Although important no special adjustment is necessary for this variable.

g. <u>Traffic Interruptions</u>. Each is a special case and must be evaluated and applied to the previous results.

h. <u>Surface Condition</u>. Insufficient data are as yet available to permit development of adjustment factors, so judgment is required in the selection of such factors in the HRB method. Further research is required to quantify these factors. (Factors used in other methods may be used as a guide). The multiplicative factor selected is then applied.

i. <u>Alinement</u>. The effect of the quality of alinement on capacity is discussed in terms of <u>average</u> highway speed and the percentage of the highway having 1500-ft passing sight distances (for 2 or 3 lane highways). These effects are incorporated in the traffic volumes given in Table 9 and do not require independent consideration.

j. <u>Grades</u>. Passenger cars are usually able to maintain travel speed up to 7% grades, whereas that of trucks tends to deteriorate with the percent of grade, the length of grade, and the existence of vertical curves within the grade. Grade is conveniently measured by the reduction in speed. However, these values are not used directly in the HRB method but are converted into passenger car equivalents (PCE).

k. <u>Passenger Car Equivalents</u>.

(1) In level terrain it has been found that the typical truck is equivalent to two passenger cars on multilane highways and between two and three on two-lane highways. On upgrades the PCE may vary widely depending on steepness and length of grade and number of lanes.

(2) On two-lane highways PCE are relatively easy to obtain, but considerably more research is necessary on multilane highways. What study has been made is at the Level B and extrapolated to Level E (capacity). Average PCE are given in Table 11 to be used when detailed information is lacking.

TABLE 11. AVERAGE PCE FOR TRUCKS (E_T)

Level of service	PCE level	PCE rolling	PCE mountainous
TWO LANE			
A	3	4	7
B and C	2.5	5	10
D and E	2	5	12
MULTILANE RURAL AND FREEWAYS			
A	Widely Variable. Use PCE for remaining levels.		
B thru E	2	4	8

1. Example: Capacity of hypothetical highway from A to B. Because of the inability to evaluate all of the significant factors from the data furnished, only the theoretical maximum is computed as an illustration. The practical maximum is normally lower than the theoretical, but the theoretical will serve for comparison. For instance, the lateral clearance factor discussed above is evaluated at 0.74 and can be applied to the result of the example by taking 74 percent of the theoretical maximum. This is not done because the application of one factor and none of the others may tend to be misleading.

Level of service: E (30 mph)(capacity), then V = 2000
From Table 10, W = .81, From Table 11, E_T = 5

$$C = \frac{100 \times 2000 \times 1 \times .81}{100 + 100\ (5-1)} = 324 \text{ trucks per hour}$$

324 x 20 = 6480 trucks per day (theoretical maximum)

9. RAND Method (Manual for Computing Road Capacity, 1964).

a. The RAND method relates truck requirements to road capacity. Penalties for terrain, surface condition, and narrow widths are paid in terms of extra trucks required rather than in terms of reduced capacity.

b. Before this method can be used, it is necessary to convert input data on roads into standard categories as follows:

Roads

Waterproof Surface, Road Types 1, 2, 4, 5
Metalled Surface, Road Type 6
Natural Surface, Road Types 7, 8

Terrain

Flat	Grade up to 5%, Radius of Curce >150'
Hilly	Grade up to 5-7%, Radius of Curve >100-150'
Mountainous	Crade up to 7-11%, Radius of Curve <100'

Width

Adequate ≥20'
Narrow <20'

Condition

Poor	Not defined
Fair	Not defined
Good	Not defined

c. To eliminate the necessity for roadway and traffic adjustment factors, observations were taken on road speeds naturally assumed by the drivers of the four test trucks and reduced 20 percent to allow for large scale movements. (See Table 12.)

d. The truck rate, or trucks forward per hour, is a function of the ratio of lead to speed--the speedometer-multiplier concept. The ratios obtained from the field test were modified to convert to convoy operation by (1) multiplying 1.87 to allow for space between march elements, (2) increasing the ratios to allow for moderate to heavy dust conditions, and (3) further increasing the ratio in the case of two-way roads to allow for breathing space after trucks had passed opposing traffic.

e. Headways ads) observed, after modification, usually corresponded to at le. .nose for open column in convoy and often to those for infiltration.

f. Maximum road capacities, in terms of vehicles per hour in one direction, and reversing flow on one-way roads to allow for return empty, are given in Table 13.

TABLE 12. OPERATIONAL SPEEDS IN MILES PER HOUR

Surface	Adequate Width			Narrow Width		
	Flat	Hilly	Mountainous	Flat	Hilly	Mountainous
Waterproof						
Poor	12.5	12.5	12.5	12.5	12.5	12.5
Fair	23	18	15	15.5	15.5	15
Good	30	18	15	15.5	15.5	15
Metalled, dry						
Poor, light dust	12.5	10.5	10.5	10.5	10.5	10.5
, heavy dust	9.5	9.5	9.5	9.5	9.5	9.5
Fair, light dust	20.5	15	12.5	12.5	12.5	12.5
, heavy dust	9.5	9.5	9.5	9.5	9.5	9.5
Good, light dust	22.5	18	15	12.5	12.5	12.5
, heavy dust	9.5	9.5	9.5	9.5	9.5	9.5
Metalled, wet						
Poor	10	8.5	8.5	8.5	8.5	8.5
Fair	16.5	14.5	12	10	10	10
Good	18	14.5	12	10	10	10
Natural, Dry						
Poor, light dust	8.5	8.5	8.5	8.5	8.5	8.5
, heavy dust	8.5	8.5	8.5	8.5	8.5	8.5
Fair, light dust	12	12	12	9.5	9.5	9.5
, heavy dust	9.5	9.5	9.5	9.5	9.5	9.5
Good, light dust	15	15	15	9.5	9.5	9.5
, heavy dust	9.5	9.5	9.5	9.5	9.5	9.5
Natural, Wet						
Poor	7	7	7	7	7	7
Fair	10	10	10	7.5	7.5	7.5
Good	12	21	12	7.5	7.5	7.5

TABLE 13. MINIMUM TRUCK RATES (TRUCKS FORWARD PER HOUR WITH NO ENROUTE STOPS)

Surface	Season	Dust	2-Way	1-Way
Waterproof	All	None	147	55
Metalled or Natural	Dry	Light	76	37
		Moderate	62	30
		Heavy	51	25
	Wet	Light	76	37

g. The RAND Method is convoy oriented and includes consideration of a "stop factor" (halts) and cargo handling time. Table 13 gives maximum capacities and does not include these two factors. The stop factor is the fraction of travel time for routine stops (rest, meals, refueling, etc.) plus non-routine stops (ferries, fords, etc.) plus 1.0.

h. Values must be assumed for the operating period, in-commission rate, cargo handling time, truck payloads, interference with other traffic, and number of trucks available if capability is to be computed rather than capacity.

i. The method is best illustrated by the use of a worksheet, as shown in Fig 2. The method was obtained from the number of trials during in situ experiment. No attempt was made, in comparing results of the methods applied to a standard example, to extrapolate to the conditions of the standard, since sophisticated roads did not exist in the area in which the experiment was conducted. The comparison is therefore incomplete. The manner in which capacity estimations are derived is illustrated in the computations following the work sheet.

j. Route Calculations.

Maximum route capacity (vehs) = (lowest truck rate) x (operating period.)

Maximum route capacity (STONS) = (max. vehs) x (payload).

Maximum number of trucks = (lowest truck rate) x (route turnaround time) ÷ (in-commission rate).

Truck limited route capacity = (max. route capacity) x (trucks available) ÷ (max. number of trucks).

k. Example.

Max route capacity (vehs) = 60.8 x 20 = 1216

Route #: 12 Season: dry In-Commission rate: 0.75 Trucks available: 1000

Operating period: 20 hrs Payload: $3\frac{1}{2}$ STONS

No.	Road Link From	To	Length (miles)	Surface	Width (ft)	Category	Condition	Terrain	Dust	Speed (mph) (1)	Stop Factor	Truck Rate (2)	Round Trip Time (hrs) (3)
A			15	Wtpf.	20	2A	F	hilly	--	18	1.25	117.6	2.08
B			15	Wtpf.	20	2A	F	flat	--	23	1.25	117.6	1.63
C			15	Wtpf.	20	2A	G	hilly	--	18	1.25	117.6	2.08
D			15	Wtpf.	20	2A	G	flat	--	30	1.25	117.6	1.25
E			20	Met.	18	2N	F	flat	light	20.5	1.25	160.8	2.44
F			23	Met.	18	2N	F	flat	light	20.5	1.25	60.8	2.80

Total route length: 103

Route roundtrip: 12.28
Cargo handling: 4.00 hrs.

Route turnaround time: 16.28

(1) Obtain speed from Table 12

(2) Truck rate = [(max. truck rate, Table 20) ÷ stop factor] - (other traffic)

(3) Link roundtrip time:

Two-way links -- 2 x (link length) x (stop factor) ÷ speed
One-way links -- 4 x (link length) x (stop factor) ÷ speed

2A = 2 lane adequate   2N = 2 lane narrow

FIG 2. ROAD CAPACITY WORKSHEET (EXAMPLE)

$$\text{Max number of trucks} = \frac{60.8 \times 16.28}{0.75} = 1320$$

$$\text{Truck limited route capacity (vehs)} = \frac{1216 \times 1000}{1320} = 921$$

10. Findings of the RAC in Situ Study of European Roads.

a. This section documents the findings of extensive observation of European traffic on autobahns and primary roads, and as an adjunct to the requirement to structure the amassed data in a data base for the ETNAM. It has no official status as yet and was not used in forming the data base.

b. The findings of the European Theater Transportation System (ETTS) study are considered important to the identification and quantification of the factors influencing the estimation of capacity. These findings are summarized briefly, as follows:

(1) Road construction characteristics.

Autobahns (routes, strada, freeways, etc.) and primary roads: well-drained; types 1 or 2 (with some 3) surface; generally multi-laned but with some two-lane primaries; land width 10' to 12'; shoulder width varying from 2' to 6' on each link, frequently with short posts to discourage traffic; bridges 80 to 100 tons capacity. No towns or cities on autobahns. Secondary roads: for comparatively short stretches some secondaries were as good as, or better than, some of the primaries; most had surfaces well above the surrounding area indicating many resurfacing layers; type 4 and 5 surface; mostly two-laned; lane width 9' to 12'; shoulders frequently blocked by large trees but widths generally 0' to 2'; bridges 40 to 80 ton capacity.

(2) Alinement.

Autobahns and primary roads: no sharp curves observed in 3000 miles of travel; grades up to 7 percent, varying in length from 1 mile to 3 miles, with one exception, about 5 miles; grades of these magnitudes were infrequent. Secondary roads: characterized by sharp, almost right angle curves, either isolated or occurring in rapid sequence, however, there were many long level tangents; frequent towns and some cities; grades 7 percent and above usually not long except in mountainous country where there were grades 7 percent and above, with several hairpin curves, and about 2 or 3 miles long.

(3) Maintenance.

All roads: most damage seemed to be caused by frost, evidenced by surface spalling, aggravated by heavy traffic unless immediately repaired; some evidence of cracking repaired by sealing on all roads. New construction and reconstruction on multi-laned

highways reduced speed but not flow. In minor repair or resurfacing on two-lane highways one lane was blocked and the other used to alternate flow. Many towns were installing underground structures and a lane was blocked for months, usually taken care of by detours, but on an appreciable percentage no detour was possible and flow was reversed at frequent intervals.

(4) Speed and gap between vehicles.

It is in this feature that the greatest disagreement among most methods appeared. On autobahns and primary roads, always with a heavy truck flow, the truck lane sustained speed seldom varied from 50 mph, the left lane (passenger cars) varying from 60 mph to well over 100 mph. There was no discernible effect on speed caused by narrow shoulders. On secondary roads, trucks sustained a speed of 35 mph on tangents but slowed to 10 to 20 mph on curves or curved stretches. On all roads heavy grades slowed trucks. Generally lines of trucks on the grade at crawl speed (5-7.5 mph) prevented following trucks from hitting the grade at the normal speed, so the entire length of the grade was at crawl speed. Curves on these grades had no additional effect on speed. The gap between trucks on all roads was almost invariable measured by a speedometer multiplier SM of 1 or less. In rain it rose to 2 or 3 (with about 30 percent increase in speed), and with snowcover to 3 or 4 with a corresponding decrease in speed seldom exceeding 25 mph. In fog, speed decreased, depending on visibility, down to actual road closure. When moving in fog some drivers drove at an SM less than 1 and others drove at the limit of visibility of the tail light.

Very few convoys were observed but those that were were using SM = 2 or 3, speed 25-35 mph.

In towns and cities mandatory speed limits are specified and speed ranged from 20 to 25 mph.

(5) Truck payloads.

(a) This is another area of disagreement with present capacity estimation. Payloads of 20 tons to 40 tons (with trailer) were the mode on the line hauls. Local truck traffic varied too greatly to be estimated. A major finding was the difference in the observed increase in speed and reduction of the gap between vehicles as compared to values used in the standard method. Table 14 is the computation of the theoretical vehs/hr/lane of various speeds and gaps, the values of which are obtained from the equation:

$$VPH = \frac{1760 \text{ yds}}{(SM \times speed) + \text{vehicle length (yds)}} \times \text{speed (mph)}$$

TABLE 14. VEHICLES PER HOUR PER LANE*

SM	10 MPH	15 MPH	20 MPH	25 MPH	30 MPH	35 MPH	40 MPH	50 MPH
5	295	310	320	325	330	333	335	340
4	350	375	390	400	405	411	415	420
3	440	480	505	520	530	536	540	550
2	590	665	705	703	755	770	785	880
1	880	1055	1170	1260	1320	1370	1410	1470

*For Table 14, vehicle length is taken as 10 yds.

(b) Existing methods assume constant speeds on highway routes. Theoretical capacity is reduced by more or less subjective evaluations of the factors associated with the physical characteristics of the routes, day/night operation, and seasonal variation. No method considers speed or time variations within towns en route or in which the origins or destinations are located, or attempts to examine accurately the delays caused by controlled intersections, railroad crossings, repair or preventive maintenance expectancy, weather probabilities, etc.

(c) General. The effect of shoulder width is debatable. A fairly constant speed was observed all along routes where shoulder width varied considerably. Where accidents occurred the shoulder was used by disabled vehicles and the inevitable "rubberneck" factor was observed, but this also occurred when shoulder width was very small and the disabled cars were pushed into a ditch. The question arose as to the evaluation of this factor when the shoulder width was narrow for a small percentage of the route (as on bridges) or prevailed for over 50 percent. There are no guidelines for shoulder evaluation in any of the methods, and a variation of 40-50 percent may result from the selected factor values by different persons, since all factors are multiplicative.

(d) No basis could be discovered for the range of factor values associated with maintenance. Subjective selection of these values also contribute to large variations in capacity estimates.

(e) Extrapolation of the effects of factors not considered, or aggregated in standard methodologies, indicated that with an SM of 1 at 35 mph as many as 17000 vehicles per day could be accommodated. By way of comparison, a history of the European Theater in WW II[6] reports 1700 vehs/hr passing a given point on one road during

[6] Ruppenthal, Logistical Support of the Armies, Vol I. The Office of the Chief of Military History.

the Normandy invasion. At an SM of 4 the road would accommodate only 5550 vpd at a speed of 35 mph instead of a maximum of 34000 vpd as indicated by the 1700 vehicle volume.

(f) All this indicates is that highway capacity estimates may be far too restrictive and that estimate methodology should be re-examined. Underestimation (or overestimation for that matter) may result in faulty mobility force structures, faulty estimations of the size force that can be supported, or force faulty utilization of lesser preferred modes.

11. Computation of Condition Coefficients. The computation of condition coefficients, as required in the ETNAM data base for highways, is best described by an example. Consider the following road:

Length:	103 miles
Cities:	Origin is 5 miles within City A Destination is 1 mile within City B
Towns:	5, averaging 1 mile in length
Controlled Intersections:	3 near City A 1 railcrossing near City B (4 trains daily, 5 minutes delay each)
Road width:	20 ft., 1 lane in each direction
Surface:	Type 2
Road:	Primary rural
Alinement:	7% gradients (2) each 1 mile long - with 3 sharp curves
Bridges:	Adequate
Observed speed, lane:	35 mph
urban:	20 mph
Observed SM:	1
City Intersections:	5 per mile

The computations are:

$$\text{Length} = 103 \text{ miles}, \frac{103}{35 \text{ mph}} = 2.94 \text{ hrs}$$

(1.71 mins/mile or 0.58 miles/min)

3 isolated intersections: signal timing at 1 minute interval each direction. Reducing speed to 0 and then accelerating to 35 mph in another minute.

Probability of a 6 minute delay	= 0.125	(3 signals)
Probability of a 4 minute delay	= 0.375	(2 signals)
Probability of a 2 minute delay	= 0.375	(1 signal)
Probability of no delay	= 0.125	(No signals)

Average delay per vehicle =

6(0.125) + 4(0.375) + 2(0.375) + 0(0.125) = 3 minutes

3 minutes @ 35 mph = 1.74 miles

5 towns: Reduce from 35 mph to 20 mph (20 mph = 3 mins/mile 0.33 miles/min).

3 - 1.71 = 1.29 mins/mile
1.29 x 5 miles = 5.45 minutes
or 3.74 miles @ 35 mph

6 city miles: 35 mph to 20 mph
1.29 x 6 miles = 7.74 minute or 4.49 miles

5 city intersections per mile = 30 intersections
= 30 minutes or 10 miles @ 20 mph

(since the correction has already been made on speed reduction)

1 railcrossing: 4 trains per day x 5 minutes per train = 20 minutes or 11.6 miles @ 35 mph (on the assumption that the gaps created are not made up by subsequent speedups).

2 7% grades 1 mile long. Speed reduction 35 mph to 5 mph, curves have no independent effect.

35 mph to 5 mph = 7 miles per grade or 14 miles.

Total equivalent length of the A to B link =

103 + 1.74 + 3.74 + 4.49 + 10.0 + 11.60 + 14 = 148.57 miles;

$\frac{148.57}{35}$ = 4.24 hours or 4.24 - 2.94 = 1.30 hours delay

$\frac{\text{148.57 miles equivalent length}}{\text{103 miles physical length}}$ = 1.44 (condition coefficient)

This is the penalty placed on the road that assures selection of a better, although possibly longer, road.

12. Highway Transportation Resources.

a. The host nation census of vehicles is given in each of the country annexes to furnish some notion of the highway support level to be expected.

b. Actual production of units vary, and an insight into this variation may be obtained from a recent report[7] concerning daily productivity in South Vietnam (Table 15). The design capabilities of military truck units are given in Table 16.

TABLE 15. DAILY PRODUCTIVITY, SOUTH VIETNAM

	Port clearance		Local haul			Line haul		
Type truck	Av.load (STONS)	Trips per day	Av.load (STONS)	Trips per day	Dist (miles)	Av.load (STONS)	Trips per day	Dist (miles)
$2\frac{1}{2}$ ton	3.2	6.8	2.2	2.0	16.6	3.8	1.07	55.9
5 ton	5.1	1.91	5.8	2.1	12.8	4.9	1.1	79.7
5 ton w/ trailer	13.7	1.02	4.0	3.5	15.0	2.9	1.05	31.7
5 ton S&P	11.6	11.54	12.9	1.8	18.9	10.7	1.14	71.5
$6\frac{1}{2}$ ton Commercial	4.1	3.45	3.9	3.9	15.6			

c. Comparison of the military unit daily productivity with design capability shows:

	Actual productivity[7]		Design capability[7]	
	Local haul (STONS)	Line haul (ton miles)	Local haul (STONS)	Line haul[8] (ton miles)
Lt. Truck Co.($2\frac{1}{2}$)	299.1	8385	720	22500 @ $2\frac{1}{2}$ STONS payload (off road) 36000 @ 4 STONS payload
Lt. Truck Co. (5)	243.4	15709	1080	33750 @ 3 3/4 STONS payload (off road) 54000 @ 6 STONS payload)
Med. Truck Co.	337	15287	2160	67500 @ $7\frac{1}{2}$ STONS payload (off road) 108000 @ 12 STONS payload

[7] Planning Research Corp. R-1240 Vol II, Mar 196[illegible], pp II 285-289(U)

[8] Line haul average distance taken as 100 miles one way.

d. The low productivity is explained by very low vehicle availability, low driver availability, and restriction of operations to daylight hours.

e. Similar information was not available for Europe.

TABLE 16. TRUCK (MOTOR) UNITS

Unit	TOE	Mission	Capability
Transportation Light Truck Co.	55-17C	To provide transportation for the movement of general cargo and personnel by motor transport.	At full strength, with 45 trucks available making four round trips per day in local hauls or two round trips per day (one per 10-hour shift) in line hauls, a light truck company can transport the following: a. When equipped with $2\frac{1}{2}$-ton trucks: (1) For local hauls-720 STONS of cargo (4 tons per truck) based on 75% availability of vehicles and 4 trips daily on highway or 3,600 passengers (20 passengers per truck) on or off highway. (2) For line-hauls—360 STONS of cargo (4 tons per truck) based on 75% availability of vehicles and 2 trips daily on highway or 1,440 passengers (16 passengers per truck) on or off highway. (3) 112.5 STONS of cargo ($2\frac{1}{2}$-tons per truck) in one lift off highway.

TABLE 16. TRUCK (MOTOR) UNITS (CON)

Unit	TOE	Mission	Capability
			b. When equipped with 5-ton trucks: (1) Local hauls—1,080 STONS of cargo (6 tons per truck) based on 75% availability of vehicles and 4 trips daily on or off highway or 3,600 passengers (20 passengers per truck) on or off highway. (2) Line-hauls—540 STONS of cargo (6 STONS per truck) based on 75% availability of vehicles and 2 trips daily on highway or 1,620 passengers (18 passengers per truck) on or off highway. (3) 180 STONS of cargo (4-tons per truck) in one lift off highway.
Transportation Medium Truck Co.	55-18G	To provide transportation for the movement of general cargo, bulk petroleum products, and refrigerated cargo by motor transport.	a. At full strength, with 45 semi-trailer combinations available making 4 round trips per day in local hauls or two round trips per day (one per 10-hour shift) in line-hauls, a medium truck company can transport the following:

TABLE 16. TRUCK (MOTOR) UNITS (CON)

Unit	TOE	Mission	Capability
			(1) When equipped with 12-ton cargo semi-trailers: (a) Local hauls—2,160 STONS of cargo (12 tons per semi-trailer) or in an emergency only 9,000 passengers (50 passengers per semi-trailer). (b) Line-hauls—1,080 STONS of cargo (12 per semi-trailer) or in an emergency only 4,500 passengers (50 passengers per semi-trailer). (2) When equipped with 5,000-gal petroleum semi-trailers: (a) Local hauls—900,000 gallons. (b) Line-hauls—450,000 gallons.
Transportation Cargo Carrier Company (tracked).	55-27G	To provide transportation for supply distribution in regions where wheeled vehicles cannot operate effectively.	At full strength (level 1) this unit is capable of the following: a. With all vehicles available, transporting in one lift 288 STONS of cargo. b. In sustained operations, based on 75% vehicle availability, transporting 216 STONS of cargo or, when equipped with tank units, transporting 43,200 gallons of fuel 50 miles forward daily.

TABLE 16. TRUCK (MOTOR) UNITS (CCN)

Unit	TOE	Mission	Capability
Transportation Heavy Truck Co.	55-28G	To provide truck transportation for the movement of tanks and other heavy or bulky vehicles and to transport heavy, bulky, or outsized cargo.	At full strength, operating two 10-hour shifts per day, with 18 tractor trucks and semi-trailers available, this unit can: a. For local hauls—transport 2,880 STONS of cargo or tanks or similar vehicles, averaging 40 tons per truck, four round trips daily. b. For line-hauls—transport 1,440 STONS of cargo or tanks or similar vehicles, averaging 40 STONS per truck, two round trips daily.
Transportation Light-Medium Truck Company	55-67G	To provide transportation for the movement of general cargo and personnel by motor transport.	The capabilities outlined below are based on the $2\frac{1}{2}$-ton truck carrying $2\frac{1}{2}$-STONS of cargo or 20 passengers and the $1\frac{1}{2}$-ton trlr carrying $1\frac{1}{2}$-STONS of cargo. The 5 ton trk-trac with 12 ton S&P semi-trailer carries 12 STONS of cargo or 50 passengers. At full strength with all vehicles available in a one-time lift, the $2\frac{1}{2}$-ton truck with $1\frac{1}{2}$ ton trailer can lift 240 STONS or 1200 passengers and the 5-ton truck-tractor with 12-ton S&P can lift 120 STONS or 500 passengers for a total lift of 360 STONS or 1700 passengers.

TABLE 16. TRUCK (MOTOR) UNITS (CON)

Unit	TOE	Mission	Capability
			At full strength, 75% vehicles available in a one-time lift, the $2\frac{1}{2}$-ton truck combination can lift 180 STONS or 900 passengers and the 5-ton combination can lift 96 STONS or 400 passengers for a total lift of 276 STONS or 1300 passengers. For local haul, 15 miles forward, two-shift operation, 75-80% vehicle available and 4 trips of cargo and 6 trips of passengers, the $2\frac{1}{2}$-ton truck combination can lift 720 STONS or 5400 passengers and the 5 ton combination can lift 384 STONS or 2400 passengers for a total lift of 1104 STONS or 7800 passengers. For line-haul, 75 miles forward, two-shift operation, 75-80% vehicle availability 2 trips daily, the $2\frac{1}{2}$-ton truck combination can life 360 STONS or 1800 passengers for a total of 552 STONS or 2600 passengers.
Bus Squad (team GB)	55-540G	To transport personnel or litter patients by bus.	Transporting 185 passengers (5 available busses carrying 37 passengers each) or 90 litter patients (5 available busses carrying 18 litter patients each) per lift in local haul.

TABLE 16. TRUCK (MOTOR) UNITS (CON)

Unit	TOE	Mission	Capability
Heavy Truck Squad (team GC)	55-540G	To transport general and outsized or heavy lift cargo by heavy truck-tractor semi-trailer combinations.	Operating two 10-hour shifts, transporting 150 STONS per lift in local or line-haul based on 50 STONS per each of three available truck-tractor semi-trailer combinations.
Light Truck Squad (team GD)	55-540G	To transport personnel or cargo by light truck.	(1) 32 STONS of cargo or 160 passengers per lift based on eight available $2\frac{1}{2}$-ton trucks and $1\frac{1}{2}$-ton cargo trailers. (2) 52 STONS of cargo or 176 passengers per lift based on eight available 5-ton trucks and $1\frac{1}{2}$-ton cargo trailers.
Med Truck Squad (team GE)	55-540G	To transport general cargo, bulk petroleum products or refrigerated cargo by med truck-tractor semi-trailer combination.	(1) 96 STONS of cargo per lift based on eight available 12-ton stake and platform semi-trailers each carrying 12 STONS. (2) 40,000 gals. of bulk petroleum per lift based on eight available 5,000 gal. petroleum semi-trailers. (3) 60 STONS of refrigerated cargo in on lift based on eight available semi-trailer tractor combinations ($7\frac{1}{2}$ STONS refrigerator semi-trailer) each carrying 7.5 STONS.
Trailer Transfer Point Operations (team GF)	55-540G	To operate a trailer transfer point, marshalling yard or truck terminal in conjunction with line-haul operations.	Operates in conjunction with a line-haul operation, a trailer transfer point with a maximum capacity of 250, 12 STON trailer units in and out per day.

CHAPTER 5. RAIL

1. Rail Capacity Estimation[1].

a. Two methods for rail capacity are discussed in this chapter. Method 2, used in the references for determining rail capacity and the determination of engine and rolling stock requirements, makes use of a number of basic formulas in the detailed computations. These basic formulas are introduced below to furnish background to the later discussion of the two methods. Method 2 requires a knowledge of and operational data on the rail system in considerable detail. Since this information was not available, Method 1 was used in obtaining capacities for the data base.

b. Basic Formulas.

(1) Tractive Effort, Starting (T_s) and Continuous (T_c). Tractive effort is the horizontal force exerted by the locomotive. Normally, the adhesion factor dry is 30% of the weight on drivers, the adhesion factor wet is 20%, and for general planning 25% is used. Continuous tractive effort is one-half the starting effort. The US Army locomotives used for foreign and domestic service are:

	Weight on drivers (tons)	T_s (lbs) @ 25%	T_c (lbs)	P (lbs)	Min Radius (ft)	Gals fuel per train mile
131 ton, DE, 0-6-6-0, Road Eng.	131	65,500	32,750	30,120	231	2.5
127 ton, DE, Road Eng.	127	63,500	31,750	29,210	231	2.5
45 ton, DE, 0-4-4-0, Switcher	45	22,500	11,250	10,350	50	0.7
60 ton, DE, 0-4-4-0, Combination	60	30,000	15,000	13,800	75	0.9

(2) Drawbar Pull (P). Drawbar pull is that force required to start the locomotive on straight, level track. For general planning 20 pounds per ton of locomotive weight is subtracted from T_c (shown in the above table). Maximum P is exerted up to 10 mph. At higher speeds diesel-electric (DE) locomotive drawbar pull diminishes rapidly.

(3) Rolling Resistance (R). This is the resultant of the force components acting on a train parallel with the track in an opposite direction. There is no absolute figure but experience indicates safe average values as follows:

[1] Sources: [FM 55-20, FM 55-15, German Federal Railroad Freight Cars (DB Pamphlet), Janes World Railways 19[illegible], Gueterwagen Der Deutschen Bundesbahn (Data Sheets)]

Condition of track	Pounds per ton of train
Excellent	5
Good to fair	6
Fair to poor	7
Poor	8
Very poor	9 and 10

(4) Grade Resistance (G). For general planning the factor of 20 pounds per ton of train per percent of grade is used. The ruling grade usually is the determining characteristic, but if the grade is excessive, P may be increased by double-heading.

(5) Curve Resistance (C). In the US engineers usually allow 0.8 to 1.0 pound per ton of train per degree of curve. In military planning the factor of 0.8 is generally used. See Table 17.

TABLE 17. RELATIONSHIP BETWEEN RADIUS AND DEGREE OF CURVATURE

Degree	Radius (ft)	Degree	Radius (ft)
1	5730	10	573
2	2865	11	521
3	1910	12	478
4	1433	13	441
5	1146	14	409
6	955	15	382
7	819	16	358
8	716	17	337
9	637	18	318

(6) Weather Factor (W). Ordinarily wet weather is regarded as local and temporary and is considered absorbed by average figures. In countries having extended wet seasons the applicable reduction factor is a matter of judgment. In general, tractive effort (T_s) will not be reduced to less than 20% of the weight on drivers. The temperature below 32°F has a graduated effect on the tractive effort as shown in the following:

Most adverse temp in deg. F	Weather factor
Above +32	1.0
+16 to +32	0.95
0 to +15	0.90
-1 to -10	0.85
-11 to -20	0.80
-21 to -25	0.75
-26 to -30	0.70
-31 to -35	0.65
-36 to -40	0.60
-41 to -45	0.55
-46 to -50	0.50

(7) Gross Training Load (L). Gross trailing load is the maximum weight that a locomotive may safely pull under given conditions. The formula for computation is:

$$L = \frac{P \times W}{R + G + C}$$

When more than one locomotive is used the total L is the sum of the L for all locomotives.

(8) Net Train Load (N). Net train load is the payload carried by the train. The total weight of the train (Payload plus cars) is the gross weight. The weight of the cars empty is the tare weight. The difference is the payload. A common value in military planning is: $N = 0.50L$

(9) Train Density (K).

(a) Train density is the number of trains operating over a division in each direction during a 24 hour period and may vary greatly over various divisions. Train density is a function of:

Condition and length of the main line
Number of location of passing tracks
Yard and terminal facilities
Movement control facilities and procedures
Availability of crews, motive power, and rolling stock.

The formulas for estimating K for single tracks is:

$$K = \frac{J + 1}{2} \times \frac{24 \times S}{D}$$

where

J = number of passing tracks
1 = constant (number of trains possible when J = 0)
2 = constant to convert to one direction
24 = constant (number of hours per day)
D = Length of division, in mile.
S = Average speed in miles in the hour (mih)

S is obtained from the following:

Condition of truck	Percent of grade	Average speed (mih) Single track	Double track
Excellent	1.0 or less	12	14
Good to fair	1.5 or less	10	12
Fair to poor	2.5 or less	8	10
Poor	3.0	6	8

(b) If the condition or the percent grade is not known, use 8 mih for single and 10 mih for double tracks. Where the gradient is heavier than 3%, reduce the tonnage to increase speed - a 2% reduction in gross tonnage will increase speed 1 mih.

(c) For example: (a minimum condition)

D = 90 miles
J = 13 passing tracks
S = 8 mih single track

then $K = \frac{13 + 1}{2} \times \frac{24 \times 8}{90} = 15$ trains per day in one direction (compare with 10-12 trains per day standard planning factor)

For double tracks the formula is

$$K = \frac{24}{\text{Interval between trains (in hours either direction)}}$$

(d) This assumes continuous operation which makes the capacity independent of length of division. For example with 45 minutes between trains in the above equation $K = \frac{24}{3/4} = 32$. For the 90 mile division with an average speed of 10 mih, there is 7.5 miles between trains, or $\frac{90}{7.5} = 12$ on the line but it takes only 9 hours to make the trip. Then $\frac{24}{9} = 2.7$ trips, and $2.7 \times 12 = 32$ as above.

c. <u>Method 1</u>.

(1) The general planning factors shown below are averages based on experience gained in theaters of operations. These factors are increased up to 20% as the influence of enemy activities decrease and the areas of rail operations become reasonably secure.

Single-track lines — 10 trains per day in each direction
Double-track lines — 30 trains per day in each direction
Multiple-track lines — The extra tracks are used to maintain the double tracks in operation.
Single engine net trainload — 400 STONS (20 cars @ 20 STONS per car)
Narrow gauge single engine net trainload — 300 STONS (20 cars @ 15 STONS per car)

(2) From this it is to be inferred that a single track capacity, one way, is 4000 STONS (10 trains per day x 400 STONS per trainload) per day and a double or multiple track as 12,000 STONS per day. In the

steady state content, without enemy influence, these may be increased by 20% and they become 4800 STONS and 14,400 STONS per day respectively. In the absence of details these values represent a conservative estimate of operation in reasonably secure areas under wartime conditions.

d. Method 2. See basic formulas [para 1b(1) through 1b(9)].

(1) Determine the train density (K) for each division or link.

$$\left(K = \frac{J + 1}{2} \times \frac{24 \times S}{D}\right)$$

(2) Determine the capacity for each division or link:

(a) Select T_s = (25% weight on drivers) in lbs

(b) Compute T_c = (T_s/2) in lbs

(c) Compute P = (T_c - 20 lbs/ton of locomotive) in lbs

(d) Compute $L = \left(\frac{P \times W}{R + G + C}\right)$ in STONS

(e) Compute N = (.50L)

(f) Compute each link capacity = (N x K) in STONS/day (ETNAM input)

(3) Determine network capacity using ETNAM.

2. Rail Transportation Resources[2].

a. It is necessary, in all theaters, to make use of indigenous rolling stock even though augmented by some equipment from CONUS. Generally the census of equipment indicates a more than adequate supply for military transportation alone, but it must be remembered that the host nation economy requires most of this equipment and, in friendly countries, takes precedence. In order to arrive at a fair estimate of military requirements for quantitative negotiation, the following computations are presented.

(1) Rolling Stock Requirements.

(a) Estimate % of network capacity carried in box cars

(b) Estimate % of network capacity carried in gondolas

(c) Estimate % of network capacity carried in flat cars

[2]Source: FM 55-20

(d) Compute average payload per type freight car from the relationship average payload per type car =

$$\frac{\text{rated capacity of each type freight car}}{2}$$

(e) Compute % of network capacity carried in tankers

(f) Compute % of network capacity carried in passenger cars (average payload of (e) and (f) cars = rated capacity)

(g) Compute turnaround time

Allow 2 days at origin, 1 day at destination, and 2 days transit time for each division to be traversed (division is 90 to 150 miles). Delays are accounted for by this computation.

(h) Compute rolling stock requirements for 1 day of dispatch =

$\frac{a}{d_a} + \frac{b}{d_b} + \frac{c}{d_c} + \frac{e}{d_e} + \frac{f}{d_f}$ (each is rounded up. d = total days of dispatch).

(i) Compute total requirements for each type car from:

$$\frac{\text{End delivery tonnage (Per type car)}}{\text{Av. paylaod per type car x turnaround time x 1.1 (reserve factor)}} =$$

requirements for type car.

(2) Road and switch-engine requirements.

(a) Compute road engine requirements for each division or

$$\text{link} = K \times \frac{\frac{D}{S} + 3}{24} \times 2 \times 1.2$$

where
3 = terminal time (in hours)
2 = constant for 2 way traffic
1.2 = constant for reserve

(b) Compute total road engine requirements = sum of division or link requirements.

(c) Compute Switcher requirements. (1 per 67 cars at origin or destination; 1 per 100 cars passing division terminal per day.) Add 20% reserve.

(3) Train crew requirements.

(a) Road crews.

$$K \times 2 \times \frac{\frac{D}{S} + 3}{12} \times 1.25$$

where

2	=	constant for 2 way operation
3	=	2 hour call period + 1 hour at terminal
12	=	12 hour shift per road crew per day
1.25	=	constant to allow for ineffectives

(b) Switcher crews.

Number of switchers x 2 x 1.25

where

2	=	2 crews per engine (do not include reserve engines)
1.25	=	constant to allow for ineffectives

b. Rail Rolling Stock Characteristics. The following table of cars used in foreign service is furnished as a reference in the above computations, all units are standard gauge. See Table 18.

c. Military Rail Units. The design capabilities of military rail operating units are given in Table 19.

TABLE 18. FOREIGN SERVICE ROLLING STOCK CHARACTERISTICS

Type of car	Maximum Capacity (STONS)	Av.Payload (STONS)	Tare Weight (STONS)	Length (feet)
United States				
Box, 40 ton	40	20	18.5	40.5
Flat, 40 ton	40	20	14.5	40.8
Flat, 80 ton	80	40	35.3	46.3
Flat, 70 ton, Depressed Center	70	35	41.5	50.6
Gondola, Hi side, 40 ton	40	20	18.0	40.0
Gondola, Lo side, 40 ton	40	20	16.0	40.4
Tank, 10,000 gal	35	35	19.0	NA
Europe				
Lumber car(4)	17.5	9	NA	30.5
Box car (Gmbs)	21	11	11.4	34.7
Box car (Kmmks)	24	12	11.8-15.0	32.8
Refr car (Tmehs)	20	10	NA	38.4
Flat car (Sm)	21	11	10.8	47.2
Flat car (Sslms)	56	28	24.3	65.6
Flat car (SSy)	52	26	16.0	35.4
Flat car (SSyl)	58	29	20.0	46.6
Flat car (Ssym)	82	41	22.3	43.3
Flat car (Rlmms)	27	14	12.7	45.6
Flat car (Rmms)	25.5	13	10.5	39.7
Flat car (Rms)	21	10	13.0	42.0
Gondola (Omm)	30	15	10.0	32.8
Gondola (Xlm)	21	10	8.9	34.8
Gondola (XXo)	25	13	12.0	44.0
Container (BTmms)	31.5	16	8.3	44.3
Flat car (FFlm)	95	48	32.5	51.0
Flat car (FFl)	47	24	31.8	67.0
Flat car (FF)	50	25	18.2	44.8
Tank car (16,000 gal)	69.3	69.3	23.9	40.7
Tank car (9,900 gal)	40	40	17.4	40.8
Tank car (10,000 gal)	40	40	18.6	42.1

m = less than 21 ton cap.	y = 52 tons
mm = more than 21 ton cap.	yl = 50 tons
e or h = heated	ym = 82 tons
s = 60 mph	o = immovable walls
l = loading length at least 59'	k = sliding roof

Capitol letter designates car type. Single letter is two axle, double letter is four axle.

Note. Full capacity can be achieved by high density cargo (ammo, wire, sand, stone, cement, rifles, engineer tools, etc).

TABLE 19. RAIL UNITS

Unit	TOE	Mission	Capability
Transportation Railway Train Operating Company	55-229G	To provide road and yard personnel for the operation of railway locomotives and trains.	At full strength, provides 40 train crews daily in either road or yard service operating 90 to 150 miles of railroad.
Railway Train Operating Sec Team EK	55-520G	To operate trains.	Operating three trains on a 24-hour basis in either road of switching service.

CHAPTER 6. INLAND WATERWAYS

1. Inland Waterway Capacity Estimation.[1]

a. In underdeveloped areas where other modes are lacking or insufficient, inland waterways (IWW) are utilized for military purposes when available. In all areas IWW, if they exist, can be used to relieve the pressure on the preferred modes of transportation by moving the bulk of civilian tonnage.

b. In most cases all or a portion of the information required is unavailable or unknown. Certain average factors have been developed for use when this is the case. These values are generally used in lieu of definite data values but are intended as guides only and should not be used arbitrarily without some knowledge of waterway facilities and practices in the areas under consideration.

c. There are three basic factor classes shown below affecting the capacity of a waterway, any of which may contain the limiting factor.

(1) Route characteristics.

(a) Degree of meander

(b) Current velocity and turbulence

(c) Limiting depth

(d) Tide and current reversal

(e) Lock cycle of the limiting lock

(f) Size of the limiting lock

(g) Navigational aids

(h) Seasonal icing

(i) Drought and flood

(j) Channel width

(k) Border crossings

(l) Number of locks

[1] "Agreed Methodology for Computing Capability of IWW." (Working Group Report, 1956, composed of representatives of CE, TIA, Navy, AFOIN, CIA, and Commerce.)

(2) Characteristics of terminal facilities.

(a) Quay length (prepared and unprepared)

(b) Depth at quays

(c) Materials handling equipment

(d) Availability of labor

(e) Storage capacity

(f) Clearance capacity

(g) Discharge capacity or rate

(h) Lighting

(i) Operating hours

(3) Fleet characteristics.

(a) Barge size and tow makeup (including self-propelled (SP) barges)

(b) Towboat capability (including SP barges)

(c) Draft

(d) Barge capacities

(e) Operational hours

(f) Size of the fleet

(g) Availability of labor

d. Route Characteristics.

(1) The study of the route characteristics as in (1) above results in a determination of the route limitations and the pin-pointing of the single most limiting restriction.

(2) Limitations fall into two categories: (a) time limitations caused by route characteristics; and (b) limitation on the size of craft accommodated. The most limiting of all single-point restrictions on time and size is used for determining the route limitation. The usual restriction is the longest locking cycle (t). In the absence of information, this cycle may be taken as 3/4 hours,[2] modified to reflect

[2]FM 55-15, Feb 1968

significant details that may be in the possession of the planner. Such details may include: maneuvering efficiency of the craft, adequacy of guide walls, size and lift of the lock, availability of supplementary motive power, etc. If there are no locks on the route, it may be that the longest delay is caused by meander, turbulence, tide, awaiting bridge openings, speed restrictions because of wash or scour, etc. The IWW data base was developed using the standard locking cycle of 3/4 hour. When there are no single-point restrictions, the limiting factor lies in either the terminal or fleet characteristics. Where there are single-point restrictions the following formula is used to estimate the maximum route productivity.

$$P_r = \frac{cC_r h_1}{t}$$

Where

P_r = productivity of the route in STONS/day per channel (where two-way flow is permitted, P_r is the same for each channel).

C_r = rated cargo capability of largest lift unit (single barge or multiple tow) that can pass the most limiting restriction per passage (usually a lock) in STONS.

c = percent of rated capacity available considering commodity or type of cargo hauled. (See Resource Productivity.)

h_1 = number of operating hours per day (floating craft).

t = longest delay, in hours (usually the locking cycle).

(If there are no locks or other restrictions, then $t = 0$, and the capacity of the route becomes indeterminate and ceases to be a limiting factor.)

(3) The number of operating hours per day (h_1) is not the same for all waterways and may vary with the season. There are many other factors that may influence the length of the operating day. In the absence of definite information, however, it must be assumed that operation is limited to daylight hours.

e. Terminal Characteristics.

(1) These fall into three categories: (a) berthing space as discussed below; (b) cargo handling capability; and (c) clearance capacity all expressed as STONS/day handling potential. Alongside berthing space is usually prepared space but may be the sum of the lengths of prepared and unprepared quays at which the depth is sufficient to accommodate the lift units using the terminal and for which there is a factor to convert this space into tonnage handling potential (reception capacity). Cargo handling (or discharge, loading capacity) is usually measured as the rate of tons per foot of usable berthing

space per day. Reception capacity, is thus equal to or greater than the discharge (loading) capacity and need not be considered for an estimation of terminal productivity.

(2) The formula used for discharge capacity estimation is simply:

$$P_d = brh_2$$

Where P_d = discharge capacity of the terminal (STONS/day)

b = length of usable berthing space, in linear feet

r = cargo handling rate in STONS per linear foot of berthing space per hour

h_2 = number of port operating hours per day

(3) The cargo handling rate in STONS per foot of usable berthing space per hour (r) varies considerably. In the US the rates for general (packaged) cargo lie between 1.6 to 10 STONS per 20-hour day, or 0.075 to 0.5 STONS per hour. This range is accounted for by: degree of mechanization (fixed and mobile); adequacy of working space; distance to set down; efficiency of stevedore gangs; etc. A rule of thumb for commercial barges is 10 STONS/hr/barge without materials handling equipment (MHE) and 30 STONS/hr/barge with mechanical MHE.[3]

(4) The number of operating hours per day (h_1) is not the same for all waterways and may vary with the season. There are many other factors that may influence the length of the operating day. In the absence of definite information, however, it must be assumed that operation is limited to daylight hours.

(5) The length of the working day at the terminal (h_2) is usually taken as 20 hours, but actually reflects around the clock operation and delays inherent in this operation. This is also subject to modification when some details of information are available (i.e., lighting, labor, availability, local practice, etc.).

(6) Terminal clearance tonnage capacity is the capacity of entrances and exits for clearing all cargo from the terminal. For efficient operation discharge should be equal, or nearly so, to the amount of cargo brought into the terminal for outloading. Storage facilities permit daily variations in productivity. Terminal capacity is the lesser of terminal reception capacity, terminal discharge capacity, or terminal clearance capacity.

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[3]FM55-15, Feb 1968.

(7) The details and factors of the IWW networks of the several countries under consideration are given in the appropriate chapters in Part Two, Volume IV.

2. Inland Waterway Resource Productivities.

a. Fleet productivities fall into two categories: (1) capability of the cargo craft; and (2) capability of the towing craft. Self-propelled cargo craft have both capabilities and may be computed separately. They have a longer turnaround time than tugs, that must be taken into account when they are included in the towing craft inventory. The lower of the two categories is the capability of the standing fleet.

b. The total cargo carrying capability of the fleet of IWW craft is:

$$F = QA_b$$

Where F = the total usable cargo craft capacity (STONS)
Q = sum of the cargo craft rated capabilities
A_b = availability of cargo craft (percent not deadlined)

c. The availability of cargo craft (A_b), taking consideration of craft out of service for repair, is normally taken as 85 percent of the total cargo craft inventory. This may be modified by such information as: the intensity of use of the waterway; the proportion of dumb to self-propelled barges; type of barge; availability and capability of repair facilities; age of the fleet; seasonal time available for repairs, etc.

d. The average barge load forward is:

$$U = \frac{cF}{I_b}$$

Where U = average barge load (STONS)
c = percent of rated capability available considering commodity or type of cargo hauled
I_b = number of cargo craft in inventory

e. The percent of rated cargo capability available (c) varies with the stowage factor (types of cargo). From observation in practice, military cargo utilizes only about 60 percent of the weight carrying capacity. Bulk cargoes such as coal, ore, or POL normally can be loaded in sufficient volume to utilize the vessel's maximum weight carrying capacity.

f. The productivity of the cargo carrying fleet, loaded forward and return empty is:

$$P_f = \frac{cF}{\frac{2D}{Sh_1} + \frac{U}{h_2 r} + \frac{Nt}{h_1}}$$

where
P_f = productivity of the fleet, in STONS/day
D = length of the haul one way, in miles
S = average speed in still water, in mph
U = average barge load (when the terminal is also outloading for the return trip use 2U)
h_1 = number of operating hours per day (floating craft)
h_2 = number of operating hours per day (terminal)
r = rate of handling cargo in STONS/hr/ft of wharf
N = number of restrictions on the route (generally locks)
t = longest delay, in hours (usually the lock cycle)

g. The average speed of craft in mph in still (open) water (S) varies within somewhat narrow limits. Representative averages for several countries are given in Table 20. If speed is unknown, 4 mph is generally used. This is the factor used in the IWW data base except in the few cases where other information was cited by other authentic documents.

h. Requirements for cargo craft may be computed from the above factors as follows:

$$R_f = \frac{[P_r \text{ or } P_t]\ [\frac{2D}{Sh_1} + \frac{U}{h_2 r} + \frac{Nt}{h_1}]^{4}}{cA_b}$$

where R_f is the requirements for cargo craft representing the aggregate tonnage of craft required to meet either the water route capability or waterway terminal capability.

i. The formula used for the estimation of towing craft capability is similar to that for cargo craft.

$$P_p = \frac{I_t\ BUA_t}{\frac{2D}{Sh_1} + W + \frac{Nt}{h_1}}$$

[4] The expression $\frac{2D}{Sh_1} + \frac{U}{h_2 r} + \frac{Nt}{h_1}$ = turnaround time (TAT) when there is no retrograde cargo, and $\frac{2D}{Sh_1} + \frac{2U}{h_2 r} + \frac{Nt}{h_1}$ = turnaround time when there is outloading for retrograde movement. The elements of the expression are navigating time plus port time plus lock time.

TABLE 20. SPEED IN OPEN WATER

	Type	Speed (mph)	Remarks
China			
	Towed Junks	6.1	
	Motorized Junks	5.2	60 ton capacity
	Packets	7.0-10.0	300-970 PAX plus 36-350 STONS cargo
	Passenger vessels	5.5-10.0	
USSR			
	2000 ton SP Barge	10.5	
	1000 ton SP Barge	10.0-11.5	
	600 ton SP Barge	8.5	
	500 ton SP Barge	9.5	
	200 ton SP Barge	8.75	
	Barge tows	2.5-3.0	Upstream on Volga only
Germany (locked waterways)	SP Barges	5.0	
	Barge tows	2.5-2.7	
Iraq (open water)	SP commercial vessels	4.8	Basra to Baghdad, high water
	SP commercial vessels	4.0	Basra to Baghdad low water
US			
	Barge tows	3.5-6.0	Mississippi
	Barge tows	4.0-8.0	Columbia and San Joaquin Rivers
	Packet Boat	8.0-11.0	Columbia and San Joaquin Rivers

Where P_p = productivity of the towing craft fleet
B = number of barges per tow
I_t = total inventory of tugs
W = time spent in port by tugs
A_t = availability rate (percent not deadlined) of tugs

All other symbols the same as before.

j. The availability of tugs (A_t) is usually taken as 80 percent of the total powered craft inventory, subject to modifications as above.

k. Requirements for towing craft may be computed from the above values as follows:

$$R_t = \frac{I_b A_b \left(\frac{2D}{Sh_1} + W + \frac{Nt}{h_1}\right)}{BI_t A_t \left(\frac{2D}{Sh_1} + \frac{U}{h_2 r} + \frac{Nt}{h_1}\right)}$$

where R_t is the requirement for towing craft to handle a given number of cargo craft.

3. Vessel Capacity Based on Dimensions.

a. The computation of vessel capacity from its dimensions is based on an examination of barges in Germany where it was found that:

$$\frac{\text{rated capacity}}{\text{craft displacement}} = 0.02 \text{ average (dumb and self-propelled)}$$

b. Where maximum capacity is unknown and only the dimension of the maximum size craft that can pass through the limiting lock are known then:

Approximate capacity of craft = 0.02 lwd (in feet
= 0.7 lwd (in meters)

l = length of craft
w = width of craft
d = loaded draft of craft

c. When a craft is adapted to the locks, a utilization of 85 percent of the volume of the lock is realizable (derived from examination of locks and craft on the Finow, Saale, Rhein-Herne Kanal, and Peniche waterways). This leads to the following:

d. Where the dimensions of the limiting lock are known, but neither the maximum capacity nor the dimensions of the largest craft that can pass through the lock are known then:

tonnage that can pass the most limiting lock = .017 lwd (in feet) or 0.6 lwd (in meters)

where
l = length of lock chamber
w = width of lock chamber
d = depth over sill

4. Military terminal and IWW operating unit capabilities are given in Chapter 8.

CHAPTER 7. PIPELINES

1. Pipeline Capacity Estimation.

a. As with all transportation modes, the capacity of a pipeline cannot be estimated with any degree of precision without accurate information concerning the many factors influencing its rate of flow. Obtaining this information is most difficult in the case of pipelines, since the most crucial determinants are inside the pipe and not discernible by external inspection.

b. Methods.

(1) Method 1. The simplest and, by all odds, the most accurate determination of capacity, is a measurement of output on the ground or by an examination of the records from any of the pumping stations or storage areas downstream from the initial input. Presumably intelligence of the area would include capacity data. Using this method, pipeline capacities in the data base were taken entirely from intelligence documents, except in Europe where capacity information was furnished by the Petroleum Distribution Command.

(2) Method 2.

(a) A second method is to use the theoretical and deceptively simple standard formula for rate of discharge:

$$Q = 0.7854\, D^2 V$$

where
Q = rate of discharge, in ft^3/sec
D = inside diameter of pipe, in feet (ID)
V = mean velocity of fluid, in ft/sec

The ID of a pipe in place is not determinable without direct measurement but may be estimated reasonably close. However, the velocity is most difficult to estimate, influenced as it is by the size and condition of the pipe, the condition and location of the pumps, working pressure, hydraulic gradient, fluid viscosity and specific gravity, among other things.

(b) It has been stated (FM 55-15) that economical velocities for American Petroleum Institute (API) pipe are ordinarily in the range of 3.5 - 5.5 ft/sec. (This may be true for commercial pipe but the rate of discharge for the pipes in the NATO Central European Pipeline System (CEPS) indicate a velocity of less than 1 ft/sec.) Thus an estimate of capacity may be obtained by substituting the assumed ID and using a velocity estimate, based on the outward appearance of the condition of the pipe, in the above formula. This is a quick estimate of uncertain reliability.

(c) When Q is obtained in ft^3/sec, as it is in this formula, it is readily converted to other measurement units as follows:

Rate of discharge in gals per second (gps) = 7.4805 Q
Rate of discharge in gals per minute (gpm) = 448.8300 Q
Rate of discharge in gals per hour (gph) = 26929.8000 Q
Rate of discharge in gals per 20 hr day (gpd) = 538596.0 Q
Rate of discharge in bbls per hour (bph) = 641.1857 Q
Rate of discharge in bbls per 20 hr day (bpd) = 12823.7140 Q
Rate of discharge in cu ft per hour (ft^3/hr) = 3600 Q
Rate of discharge in cu ft per 20 hr day = 72000 Q
Rate of discharge in cu meters per hour (m^3/h) = 1019.4065 Q
Avgas rate of discharge in STONS per hour = 79.38 Q
Avgas rate of discharge in STONS per 20 hour day = 1587.6 Q
Mogas rate of discharge in STONS per hour = 82.26 Q
Mogas rate of discharge in STONS per 20 hr day = 1645.2 Q
Diesel rate of discharge in STONS per hour = 94.14 Q
Diesel rate of discharge in STONS per 20 hr day = 1882.8 Q

Gals per ft of length = 0.0408 D^2 (in inches)
1 bbl = 5.61 cu ft = 42 gals
1 gal = 0.13368 cu ft
1 liter = 0.264172 gals
1 cubic meter = 1.307950 cu yds
= 35.314667 cu ft
= 264.171366 gals
= 6.28979 bbls

(d) Example:

Estimated ID of 6" tubing = .535 ft
V = 5.5 ft/sec
$Q = 0.7854\ D^2V$
$Q = 0.7854 \times (.535)^2 \times 5.5 = 1.238\ ft^3/sec$
$1.238 \times 12823.714 = 15875$ bbls/day

(3) Method 3.

(a) A third method, an extension of the second method, is to make use of the known values of the API pipe and military tubing, as given in Table 21, as a comparative guide. The size and the outside diameter (OD) are given in the table for nominal sizes 4" to 30" OD (including military tubing). The exact ID is also given, and a velocity ratio equalizing capacity for all pipes in the nominal size class. The fluid usually examined is mogac, specific gravity 0.725.

(b) The capacity of the pipe is given in the commonly used terms at a velocity of 1 ft/sec. Pipeline fill for the static condition is also shown. Note that these values are at 60°F and a correction factor is necessary to convert fluid at any flow temperature to the standard 60°F.

(c) Example:

A 6" military line is being examined. From Table 21 the ID is 6.415" and the capacity at V = 1 ft/sec is .2244 ft^3/sec or 143.882 bph.

143.882 bph x 20 hr day = 2877.6 bbls/day

From Table 21, taking V = 5.4 ft/sec, the estimated capacity is 2877.6 x 5.4 = 15540 bbls/day.

(4) There is a fourth method in TM 5-343 that requires a higher degree of engineering knowledge and skill than that normally possessed by transportation planners. The method of capacity estimation is a reversal of the design steps outlined in TM 5-343. Because of its complexity and, perhaps, limited value at the planning level, it is not included in this presentation.

2. Pipeline Resources Estimation.

a. Information was not readily obtainable on the strength or capabilities of civilian pipeline operating elements in Europe or Asia. The military unit design capabilities are given in Table 22, and if civilian labor is available it is a reasonable assumption that operating skill is exchangeable on a one-for-one basis.

b. Productivity of any pipeline operating unit is just the flow through the pipe and there can be considerable variation for the same amount of personnel and effort.

TABLE 21

AMERICAN PETROLEUM INSTITUTE (API) STEEL PIPE CHARACTERISTICS

Nominal pipe size (ins)	Outside diameter (ft)	Outside diameter (ins)	Inside diameter (ft)	Inside diameter (ins)	Capacity @ Temp = 60°F, Velocity = 1 ft/sec: ft^3/sec	gpm	bph	m^3/hr	Pipeline fill v = o: gals/ft	bbls/100ft	bbls/mi	Vel ratio
4	.375	4.50= 4-1/2	.3360	4.0320	.0886	39.766	56.809	90.3	.6633	1.579	83.4	1.0
4	.375	4.50	.3192	3.8304	.0801	35.951	51.359	81.7	.5987	1.425	75.3	1.11
4	.375	4.50	.3020	3.6240	.0716	32.136	45.909	73.0	.5360	1.275	67.4	1.24
4	.375	4.50	.2870	3.4440	.0647	29.039	41.485	66.0	.4839	1.152	60.8	1.37
6	.552	6.624=6-5/8	.5048	6.0576	.2000	89.766	128.237	203.9	1.4974	3.563	188.2	1.0
6	.552	6.624	.4800	5.7600	.1810	81.238	116.055	184.5	1.3536	3.222	170.2	1.10
6	.552	6.624	.4580	5.4960	.1650	74.057	105.796	168.2	1.2322	2.933	155.0	1.21
6	.552	6.624	.4360	5.2320	.1470	65.978	94.254	149.9	1.1170	2.658	140.4	1.36
8	.719	8.628=8-5/8	.6780	8.1360	.3605	161.803	231.147	367.5	2.7003	6.427	339.6	1.00
8	.719	8.628	.6722	8.0664	.3550	159.335	227.621	361.9	2.6547	6.318	333.8	1.02
8	.719	8.628	.6650	7.9800	.3470	155.744	222.491	353.7	2.5983	6.184	326.7	1.04
8	.719	8.628	.6502	7.8024	.3320	149.012	212.874	338.4	2.4835	5.911	312.3	1.09
8	.719	8.628	.6360	7.6320	.3178	142.638	203.769	324.0	2.3766	5.656	298.8	1.14
8	.719	8.628	.6200	7.4400	.3020	135.547	193.638	307.9	2.2588	5.375	284.0	1.20
8	.719	8.628	.5990	7.1880	.2820	126.570	180.814	287.5	2.1082	5.017	265.1	1.28
8	.719	8.628	.5830	6.9960	.2673	119.972	171.389	272.5	1.9967	4.752	251.1	1.35
8	.719	8.628	.5664	6.7960	.2525	113.330	161.899	257.4	1.8845	4.485	236.9	1.43
10	.896	10.752=10-3/4	.8540	10.2480	.5730	257.180	367.399	584.1	4.2847	10.198	538.8	1.00
10	.896	10.752	.8460	10.1520	.5625	252.467	360.667	573.4	4.2050	10.008	528.7	1.02
10	.896	10.752	.8360	10.0320	.5500	246.857	352.652	560.7	4.1061	9.772	516.3	1.03
10	.896	10.752	.8120	9.7440	.5170	232.045	331.493	527.0	3.8742	9.219	487.1	1.11
10	.896	10.752	.7960	9.5520	.4970	223.069	318.669	506.6	3.7224	8.859	468.1	1.15
10	.896	10.752	.7744	9.2928	.4710	211.399	301.998	480.1	3.5229	8.385	443.0	1.22
10	.896	10.752	.7540	9.0480	.4460	200.178	285.969	454.7	3.3405	7.950	420.0	1.28
10	.896	10.752	.7300	8.7600	.4185	187.835	268.336	426.6	3.1308	7.451	393.7	1.37
10	.896	10.752	.7080	8.4960	.3930	176.390	251.986	400.6	2.9447	7.009	370.3	1.46
12	1.062	12.744=12-3/4	1.0220	12.2640	.8190	367.592	525.131	834.9	6.1369	14.604	771.6	1.00
12	1.062	12.744	1.0080	12.0960	.7980	358.166	511.666	813.5	5.9694	14.207	750.6	1.02
12	1.062	12.744	.9960	11.9520	.7790	349.639	499.484	794.1	5.8278	13.870	732.8	1.05
12	1.062	12.744	.9680	11.6160	.7365	330.[illegible]63	472.233	750.8	5.5048	13.102	692.2	1.1[illegible]

TABLE 21. AMERICAN PETROLEUM INSTITUTE (API) STEEL PIPE CHARACTERISTICS (CON)

Nominal pipe size (ins)	Outside diameter		Inside diameter		Capacity @ Temp = 60oF							Vel ratio
					Velocity = 1 ft/sec				Pipeline fill v = o			
	(ft)	(ins)	(ft)	(ins)	ft^3/sec	gpm	bph	m^3/hr	gals/ft	bbls/100ft	bbls/mi	
12	1.062	12.744	.9440	11.3280	.7060	316.874	452.677	719.7	5.2358	12.460	658.3	1.16
12	1.062	12.744	.9230	11.0760	.6680	299.818	428.312	681.0	5.0052	11.912	629.3	1.22
12	1.062	12.744	.8960	10.7520	.6310	283.212	404.588	643.2	4.7169	11.225	593.1	1.29
12	1.062	12.744	.8760	10.5120	.6030	270.644	386.635	614.7	4.5086	10.730	566.9	1.35
12	1.062	12.744	.8450	10.1400	.5610	251.794	359.705	571.9	4.1949	9.984	527.5	1.46
16	1.333	16.0-16	1.2920	15.5040	1.310	587.967	839.953	1335.4	9.8078	23.340	1233	1.00
16	1.333	16.0	1.2840	15.4080	1.293	580.337	829.053	1318.1	9.6855	23.052	1218	1.01
16	1.333	16.0	1.2700	15.2400	1.265	567.770	811.100	1289.5	9.4762	22.552	1191	1.04
16	1.333	16.0	1.2500	15.0000	1.227	550.714	786.735	1250.8	9.1800	21.848	1154	1.07
16	1.333	16.0	1.2240	14.6880	1.176	527.824	754.034	1198.8	8.8025	20.948	1107	1.11
16	1.333	16.0	1.1940	14.3280	1.120	502.690	718.128	1141.7	8.3761	19.933	1053	1.17
16	1.333	16.0	1.1620	13.9440	1.058	474.862	678.374	1078.5	7.9327	18.880	997	1.24
16	1.333	16.0	1.1300	13.5600	1.002	449.728	642.468	1021.4	7.5014	17.854	943	1.31
16	1.333	16.0	1.0940	13.1280	.940	421.900	602.715	958.2	7.0314	16.734	884	1.39
16	1.333	16.0	1.0730	12.8760	.902	404.845	578.350	919.5	6.7638	16.099	851	1.46
18	1.500	18.0-18	1.4580	17.4960	1.667	748.200	1068.857	1699.4	12.4886	29.724	1570	1.00
18	1.500	18.0	1.4480	17.3760	1.648	739.672	1056.674	1680.0	12.3178	29.317	1549	1.01
18	1.500	18.0	1.4280	17.1360	1.602	719.026	1027.179	1633.1	11.9798	28.513	1506	1.04
18	1.500	18.0	1.4050	16.8600	1.550	695.687	993.838	1580.1	11.5980	27.602	1458	1.07
18	1.500	18.0	1.3810	16.5720	1.497	671.899	959.855	1526.1	11.2043	26.666	1409	1.11
18	1.500	18.0	1.3450	16.1400	1.420	637.339	910.484	1447.6	10.6281	25.295	1336	1.17
18	1.500	18.0	1.3060	15.6720	1.341	601.881	859.830	1367.0	10.0207	23.850	1260	1.24
18	1.500	18.0	1.2760	15.3120	1.280	574.502	820.718	1304.8	9.5654	22.766	1203	1.30
18	1.500	18.0	1.2400	14.8800	1.208	542.187	774.552	1231.4	9.0336	21.499	1136	1.38
18	1.500	18.0	1.2070	14.4840	1.145	513.910	734.158	1167.2	8.5586	20.370	1076	1.45
[illegible]	[illegible]	20.0-20	[illegible]	19.5120	2.074	930.873	1329.819	2114.2	15.5335	36.967	1953	1.00
[illegible]	[illegible]	20.0	1.6050	19.2600	2.025	908.881	1298.401	2064.3	15.1345	36.018	1903	1.02
[illegible]	[illegible]	20.0	1.5820	18.9840	1.965	881.951	1259.930	2003.1	14.7031	34.993	1849	1.05
[illegible]	[illegible]	20.0	1.5670	18.8040	1.931	866.691	1238.130	1968.5	14.4264	34.334	1814	1.07
[illegible]	[illegible]	20.0	1.5320	18.3840	1.840	825.847	1179.782	1875.7	13.7898	32.815	1734	1.12

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Nominal pipe size (ins)	Outside diameter		Inside diameter		Capacity @ Temp = 60°F							Vel ratio
					Velocity = 1 ft/sec				Pipeline fill v = o			
	(ft)	(ins)	(ft)	(ins)	ft^3/sec	gpm	bph	m^3/hr	gals/ft	bbls/100ft	bbls/mi	
20	1.665	20.0	1.4960	17.9520	1.757	788.594	1126.563	1791.1	13.1480	31.292	1653	1.18
20	1.665	20.0	1.4580	17.4960	1.670	749.546	1070.780	1702.4	12.4886	29.724	1570	1.24
20	1.665	20.0	1.4160	16.9920	1.573	706.010	1008.585	1603.5	11.7806	28.035	1481	1.32
20	1.665	20.0	1.3750	16.5000	1.484	666.064	951.520	1512.8	11.1078	26.436	1397	1.40
20	1.665	20.0	1.3450	16.1400	1.420	637.339	910.484	1447.6	10.6282	25.295	1336	1.46
24	2.0	24.0=24	1.9590	23.5080	3.015	1353.222	1933.175	3073.5	22.5465	53.659	2835	1.00
24	2.0	24.0	1.9360	23.2320	2.945	1321.804	1888.292	3002.2	22.0216	52.465	2769	1.02
24	2.0	24.0	1.9040	22.8480	2.845	1276.921	1824.173	2900.2	21.2989	50.638	2678	1.06
24	2.0	24.0	1.8880	22.6560	2.803	1258.070	1797.244	2857.4	20.9432	49.841	2633	1.08
24	2.0	24.0	1.8460	22.1520	2.673	1199.723	1713.889	2724.9	20.0210	47.649	2517	1.13
24	2.0	24.0	1.7980	21.5760	2.532	1136.438	1623.482	2581.1	18.9934	45.202	2388	1.19
24	2.0	24.0	1.7500	21.0000	2.408	1080.783	1543.975	2454.7	17.9928	42.821	2262	1.25
24	2.0	24.0	1.7080	20.4960	2.290	1027.821	1468.315	2334.4	17.1388	40.791	2155	1.31
24	2.0	24.0	1.6570	19.8840	2.155	967.229	1381.755	2196.8	16.1319	38.390	2028	1.39
24	2.0	24.0	1.6160	19.3920	2.052	920.999	1315.713	2091.8	15.3430	36.515	1929	1.50
30	2.5	30.0=30	2.450	29.4000	4.720	2118.478	3026.397	4811.6	35.2653	83.928	4434	1.00
30	2.5	30.0	2.414	28.9680	4.575	2053.397	2933.425	4663.8	34.2373	81.481	4305	1.03
30	2.5	30.0	2.396	28.7520	4.510	2024.223	2891.748	4597.5	33.7261	80.270	4241	1.05

Military Tubing

												Op.Vel.
4	.375	4.500=4-1/2	.363	4.350	.1029	46.200	65.978	104.9	.7700	1.836	97.1	5.5
6	.552	6.625=6-5/8	.535	6.415	.2244	100.728	143.882	228.8	1.6788	3.999	211.1	5.4
8	.719	8.625=8-5/8	.701	8.415	.3861	173.334	247.562	393.6	2.8989	6.876	363.3	5.6
12	1.063	12.750=12-3/4	1.040	12.481	.8495	381.318	544.687	866.0	6.3553	15.126	799.1	12.5

Note: If velocity is unknown, use 4.5 ft/sec to multiply capacity values given in the table for v=1 ft/sec. This is assuming the line is in good condition and is in hydraulic balance, i.e., pumps of sufficient capacity in proper location. In an emergency, capacity may be increased 10 percent for a period no longer than 24 hours.

TABLE 21. AMERICAN PETROLEUM INSTITUTE (API) STEEL PIPE CHARACTERISTICS (CON)

Nominal pipe size (ins)	Outside diameter		Inside diameter		Capacity @ Temp = 60°F							Vel ratio
					Velocity = 1 ft/sec				Pipeline fill v = o			
	(ft)	(ins)	(ft)	(ins)	ft^3/sec	gpm	bph	m^3/hr	gals/ft	bbls/100ft	bbls/mi	

Coefficients of expansion per °F to correct to 60°F (correction factors for density)

Jet fuel, kerosene	.0005	0° = 1.0300	60° = 1.0000	100° = 0.9800
Mogas	.0006	0° = 1.0360	60° = 1.0000	100° = 0.9760
Argas	.0007	0° = 1.0420	60° = 1.0000	100° = 0.9720

For example, 12" military tubing passing .8495 ft^3/sec @ 60°F passes .8750 ft^3/sec @ 0°F in 60°F equivalents - .8495 x 1.03 = .8750 (velocity constant @ 1 ft/sec)

TABLE 22. POL UNITS

Unit	TOE	Mission	Capability
Petroleum Operating Co.	10-207G	To operate military petroleum terminal and pipeline facilities for the storage and distribution of petroleum products for which the petroleum organization has supply responsibility.	(1) Operates petroleum terminal facilities for the receipt, storage, bulk transfer, issue and distribution of petroleum products for which the petroleum intersectional command has supply responsibility to include: a. Operation on a twenty-four-hour basis of a tank farm complex for storage of 100,000 to 500,000 barrels of bulk petroleum depending on capacity and type of storage facilities constructed in accordance with drawings in TM 5-302. The complex consists of two tank farms, each with a capacity ranging from 50,000 to 250,000 barrels. b. Operation of loading facilities for shipment of products by coastal tanker, barge, rail tank cars and tank trucks and provides for shipment of packaged products by rail and highway. Based on 75% availability of organic vehicles provides for local delivery of 52,000 gal. of bulk products and 12 STONS of packaged products daily.

TABLE 22. POL UNITS (CON)

Unit	TOE	Mission	Capability
			(2) Operates, on a twenty-four-hour basis, four pump stations for delivery of bulk petroleum via six or eight-inch multi-product coupled pipeline. On level terrain, this constitutes the operation of approximately 100 kilometers (60 miles) of pipeline. (3) Provides 60,000 gal. of bulk storage in collapsible tanks.
7 QM Petroleum Supply Co (Army)	10-477G	To provide petroleum storage facilities and wholesale distribution of petroleum products.	(1) Distributes petroleum products to class III installations in corps and army service areas; assists in the forward movement (line-haul) of bulk petroleum as required. (2) Operates organic bulk storage and handling equipment and provides storage in collapsible tanks per company for 480,000 gals. and per platoon for 160,000 gals. With 75% vehicle availability and for a single lift provides petroleum distribution for 8,100 gals per company and 2,700 per platoon when using 1,200 gal tank trucks and 101,250 gals per company and 33,750 per platoon when using 5,000 gal tank trucks. (3) Operates, as a portion of the field army reserve stock, two tank

TABLE 22. POL UNITS (CON)

Unit	TOE	Mission	Capability
			farm facilities (constructed and/or rehabilitated steel tankage or hasty bulk storage reservoirs) each capable of storing at least 420,000 gals of bulk petroleum.
Petroleum Bulk Storage and Issue Det (team JD)	10-500G		Provides personnel and equipment to operate one to three convoy refueling points on a single shift basis. Capable of issuing a maximum of 60,000 gals per day when supplied with bulk fuel.
Petroleum Pipeline Pump Station Det (team JL)	10-500G		Provides personnel to operate pipeline pump station, patrol approximately 15 miles of pipeline adjacent to pump station.

CHAPTER 8. WATER TERMINALS

1. Water Terminal Capacity Estimation[1].

a. There are three methods for estimating maximum port capacity in the absence of actual productivity reports, each of which is described in this chapter. Practically all ports have a potential capacity greater than that normally used in peacetime but expansion above the routine traffic is not generally justifiable except as a gamble for increased traffic. However, many minor ports are doing just this in a bid for a portion of the "container revolution" traffic and the future may see some of these ports becoming major contenders in this field. The most accurate determination of port capacity is to take the daily average commercial traffic as the planning capacity of the port. Such information from the ports was used in the water terminal data base for Europe. In all other countries the port capacities were extracted from intelligence reports since productivity by reports or detailed information required by each of the three methods was not made available to the study. The maximum port capacity may, in all cases, be greater than the traffic shows, when analyzed by any of the methods presented here.

b. Introductory to the discussion of these methods is a description of the general conditions upon which these methods are based.

2. Ports.

a. General Conditions.

(1) Port capacity estimates are based on the utilization of all wharfage that is suitable for the transfer of cargo.

(2) In the selection of suitable wharfage, consideration is given to the datum to which depths are referred. Two are presently being used: (1) chart datum, and (2) mean low water (MLW). Chart datum is more widely used and reflects a conservative depth figure as compared to MLW. Chart datum applies only in open basins. In wet docks the level is controlled by locks or gates.

(3) Wharves must have sufficient working space for transfer of cargo, or have the capacity appropriately reduced. There should be a minimum width of 60 ft. between the coping and any obstruction on a marginal quay or on any one side of a pier. When two sides of a pier are used and there are no obstructions a width of 90 ft. is deemed adequate. In all cases the approach to the wharf must have sufficient width for two-way truck or rail traffic and an avenue of egress from the approach root.

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[1] FM55-15

(4) Allowances and adjustments are made to compensate for certain static conditions that would retard cargo handling.

(5) Port capacity estimates assume:

(a) 20 effective cargo working hours per day.

(b) No allowance for adverse sea or weather conditions, enemy interference, or civil requirements.

(c) Adequate labor, stevedore gear, harbor craft, and cranage.

(d) Discharge is by ships gear only. Suitable allowance must be made for the use of shore gear, particularly in the discharge of containers.

(6) Berthing space is taken to be the length of the vessel plus its beam, the latter constituting a space considered necessary for maneuverability and safety.

b. Terminal Capacity.

(1) Terminal capacity, given in STONS/day, is the least value of terminal reception capacity, terminal discharge capacity, and terminal clearance capacity. The two types of water terminals to be discussed are: seaports and beaches. Inland waterway terminals have been discussed in the section, Inland Waterway Capacity Estimation (Chapter 6).

(2) There has been no formulation for the estimation of water terminal capacity that has been satisfactory to all planners. This is because of the extreme range of factor value and the presence of irreconcilable variables. Ports vary with each other and even within themselves.

c. Factor Method. In the application of the factor method, it is required to estimate the discharge capacity of each individual wharf or facility. To do this the actual wharfage length must be adjusted, on the basis of standard berthing requirements of ships, to obtain the actual length of the usable wharf. Vessel elements (number of hatches, gear, stowage dunnage, etc.) all have a bearing on the discharge rate but, in the application of the factor method, no evaluation is required since the factor reflects these conditions. However, consideration must be given to:

(1) The largest vessel entering the harbor that can be accommodated alongside with a loaded draft, as indicated below:

Berth class	Length (feet)	Depth (feet)	Discharge per wharf foot (STONS/day)	
A	565	31-30	1.3	Large cargo vessel (C4, C3)
B	460	29-23	1.3	Standard cargo vessel (C2, C1-b)
C	350	22-18	1.4	Small cargo vessel (C1-M)
D	250	17	2.0	Standard coaster (N3-5)
E	200	13	1.8	Small coaster
F	100	7	1.8	Lighter

(2) Wharf Factors.

(a) Location.

(b) Use (open or covered storage, repair and fitting out wharves, special purpose wharves; used to determine suitability of the port).

(c) Type (T-head, L-head, off-shore wharves, whose discharge rate is less than direct access wharves).

(d) Layout (structures and obstacles, stacking, tracks, curbs, fences, bins, terrain, deck surfacing, inadequacy of transit shed cargo doors, insufficient transit space).

(e) Alignment of face of wharf (angles and curvature).

(f) Condition (deterioration limiting full utilization).

(g) Load capacity of deck (what commodity is discharged here, has it adequate load and bearing capacity).

(h) Height of deck (should be at least 5 ft. above mean high water).

(i) Length of berth (100 ft. is required for each hatch or each lighter. For example: 350 ft. will accommodate only 3 lighters and the remainder is not usable).

(j) Tidal variation (ships may take advantage of high tide to reach their berths. Effective discharge may be reduced when along-wide depths are reduced by tide).

(3) Clearance. The sum of the clearance capacities of the exit modes.

(4) Anchorages. The number of suitable anchorages is based on the requirements of a class II anchorage (500-800 yds. in diameter, 30 ft. depth) for oceangoing cargo vessels.

(5) During WWII planners used the factor of 1 LTON (1.1 STONS) per foot of usable wharf per day. After the war it was agreed by the UK Ministry of Transport and the US Chief Engineer ETO that this was a

minimum planning figure that could be guaranteed. In 1955 a joint working group was formed for the purpose of determining how much this should be increased in the light of technological advance.

(6) This group found that there had been only one significant change in the alongside factor (double gearing of hatches) that raised the factor from 1 LTON to 1.2 TONS (1.3 STONS). In the last 1960's, the introduction of massive use of large size containers forced many ports into reconstruction to handle the increasing number of container ships and the end is not in sight. Suffice to say that containerships (with gear or without) have been discharged in no more than 10 hours and loaded in another 10 hours — and these ships are now being built 800 ft. or more long. The US Maritime Commission has announced the planned construction, by 27 ship operators, of 173 new ships, of which 58 are containerships and 28 Lighter Aboard Ship Handling (LASH) ships, the rest being bulk carriers and tankers. The typical LASH ship carries 49 lighters of 400 ton capacity and 356 containers of about 20 tons capacity each or a total of approximately 25,000 ton burden. It is indicated that for these ships the alongside factor value may be almost doubled. Therefore it is necessary to know the proportion of wharfage in a specific port that has been set aside for container handling and then reevaluate the alongside factor accordingly.

(7) Some factor values obtained from the study of military gang productivity during WWII over a $2\frac{1}{2}$ year period in several areas are given as guidance for the planner as follows:

Area	Discharge rate in STONS/day per foot of wharf
India-Burma	3.0
Middle Pacific	2.8
European	1.4
Caribbean	1.4
Mediterranean	1.2
North American	1.2
SW and West Pacific	0.9
All areas	1.3

(8) The lightering factor is larger than the alongside factor since discharge is more rapid than from a ship's hold. The adopted factor for planning has been taken as 1.6 LTONS (1.8 STONS) per foot of usable wharf per day.

(9) There are many problems in discharging cargo from ship to lighter in-stream. Winds of 15 knots or more, swells of over 3 ft., heavy rains, and tidal rips and currents may retard or hault such operation. However, once alongside these retardations no longer exist.

(10) The proportion of wharfage in a specific port set aside for lighters should be known. This is generally taken as that quayage with less than 18 ft. depth alongside, or where the wharf has not been designed for the accommodation of deep draft vessels.

d. Formula Method. Based on the hypothesis that the rate of discharge to and clearance from the wharf apron is a function of stevedore productivity, type of cargo, and vessel characteristics, the following formula was derived:

$$S = \frac{T}{\frac{c_1}{r_1} + \frac{c_2}{r_2} + \frac{c_3}{r_3} + \ldots + \frac{c_n}{r_n}}$$

where S = stevedore gang average capability, in STONS/hour

T = total tons discharged = $\sum_{i=1}^{n} c_i$

c_i = tons of cargo by type of commodity i to be discharged

r_i = rate of discharge per gang per hour per commodity type i

(1) Data such as these are difficult, if not impossible, for the planner to obtain. During WWII a comparative study was made of the loading productivity rates of civilian and military stevedore gangs; the result showed a ratio of 1.47 to 1.0. At that time the national average for a civilian gang was 13.9 LTONS (15.3 STONS) per hour. Applying the ratio to this average indicated a military gang rate as 9.46 LTONS (10.4 STONS) per hour. On the other hand, the 720 STONS/day capability of the Terminal Service Company indicates an average 36 STONS/hour sustained for a 20-hour day for the military gangs. It could very well be, in the light of recent technological advances, that this latter rate should be restudied, especially for the advisability of stating rates by type of commodity, (e.g., containers, breakbulk, ammunition, etc.). For example, it is repeated that, in discharging containers from a containership, it has been demonstrated that an entire ship can be discharged in one-half day. Having determined stevedore productivity, S, it is next necessary to examine the hatch rate. The hatch requiring the maximum number of hours represents the minimum time, in hours, that the vessel can be discharged, and is therefore the controlling hatch, H (in STONS). Examining each hatch (H) separately, H is the maximum value of the following expressions:

$$\frac{H_1}{e_1 S}, \frac{H_2}{e_2 S}, \frac{H_3}{e_3 S}, \ldots \frac{H_n}{e_n S} = \frac{H}{eS}$$

where e_1 = number of gangs working the hatch.[2]

(2) For example, a C2-S vessel is 455 ft. long with a beam of 62 ft. (total 517 ft.). Total cargo weighs 5665 tons and it is worked

[2]When working break-bulk hatches with double rigging; a gang is assigned to each hook; however due to normal interference the maximum output of the two gangs is expressed as: 1 gang plus 80% of second gang.

20 hours/day. The discharge characteristics of the hatches are as follows:

Hatch	Tons	Rig	
1	880	Single	$H_1/eS = 880/S = 880/S$
2	960	Single	$H_2/eS = 960/S = 960/S$ controlling hatch, H
3	1702	Double	$H_3/eS = 1702/1.8S = 946/S$
4	1254	Double	$H_4/eS = 1254/1.8S = 697/S$
5	869	Single	$H_5/eS = 869/S = 869/S$

Then the number of days at berth is given by the expression

$$\frac{H}{ehS} = \text{minimum days at berth} = B$$

In the above example $B = \frac{960}{1x20xS} = \frac{48}{S}$

where h = number of working hours per day.

It follows that:

$$\frac{T}{B} = \text{average tonnage discharged per day}$$

(3) To relate the formula method to the factor method, it is necessary to consider the delays caused by breakdowns, repairs, opening and closing hatches, shifting rigs, and other delays as dictated by experience. These delays may be aggregated in an average delay coefficient, d. WWII experience (the only data available) indicates that d = 0.927 on the average. To determine the factor equivalent, P, which is the tons per day per linear foot of usable general cargo wharfage used in the factor method:

$$P = \frac{dB}{L}$$

where L = length of berthing space.

(4) However, when S = 10.4 then 0.157S = 1.6 STONS/hr per foot of wharf. In the case of containerships civilian gangs have achieved a factor rate of 1.2 STONS/hour per foot of wharf or 24.0 STONS/day per foot for a 20 hour day. This was for 40 feet containers, discharging 960 STONS/hour from an 800 foot vessel and is an extremal value. The above illustrates the fact that the planner must exercise some judgment in his selection of values.

(5) The formula method provides a means of considering developments that are likely to affect port discharge capacity. These include the Rollon/Rolloff ship, electric ship cranes, the LASH ship and improved shipping techniques in unitization.

e. On Berth Method. A departure from the factor method is the on berth method that bases computations on total ship time on berth for representation operations. It has two advantages: (1) it recognizes that while a ship is on berth no other ship can use the berth; and (2) it would include such elements as stevedore productivity, opening and closing hatches, switching cars, awaiting empty cars or trucks, shifting rigs, discharging dunnage, shifting cargo, lost time on berth, minor ship repair, etc. It does not consider the time the berth is unoccupied.

(1) Relating this method to the factor method: tons per foot

$$\text{per day} = \frac{\text{total tons to discharge} \times 24 \text{ hours per day}}{\text{total hours on berth} \times \text{length of berth, in feet}}$$

f. Recapitulation. It will be noticed that the theme of most of the above is actual discharge, which is not entirely satisfactory as an estimator of port discharge capacity. A much better estimator is the berthing cycle, or time in port, e.g., time, in days, from arrival alongside of the first vessel to arrival alongside of the second vessel, or from a point in the first cycle to the same point in the second cycle (i.e., the cycle period). Although not indicated in any available publication, it is believed that the productivity of the Terminal Service Company is derived from consideration of the berth time lost (not invalidating the premise that this factor may be improved).

(1) Information gathered on over 4000 ships all over the world in a wartime environment, with respect to time in port, showed that the average days in port was 17.4, with 74.4 lost hours, indicating a delay coefficient of 0.704 instead of 0.927. Among the delays were:

Waiting convoy	22.1
Repairs	8.4
Waiting labor	5.2
Waiting cargo	5.0
Bad weather	3.4
During discharging	3.2
Waiting berth	1.7
Shifting berth	.5
Berthing, unberthing and other	23.9
	74.4 hours

(2) Another variable is congestion. A single ship in a port with no other ships in port is turned around much faster than a single ship when there are many ships in port. Surveys have shown that the discharge rate of the latter may be cut by as much as 25%. Again,

stevedore capability in congested periods varies from port to port and from commodity to commodity.

(3) It appears incumbent on the planner to validate port capacity by consideration of all information in his possession in relationship to the above data, including port traffic volume trends. The capacities in the European data base are computed on the factor value of 1.3 STONS per day per foot of usable wharf. For Asian ports the factor of 1.09 STONS per day is used, taken from Table 23.

TABLE 23. SUMMARY OF DAILY SHORT TONS HANDLED PER LINEAR FOOT OF DEEP-DRAFT WHARFAGE AT THE MAJOR SOUTH VIETNAM PORTS

Port	Linear feet of deep-draft Wharfage	Average daily short tons handled per linear foot
Saigon	4,772	1.03
Cam Ranh Bay	4,423	1.14
Qui Nhon	2,320	1.15
Danang	3,500	1.08
South Vietnam-Wide	15,015	1.09

Note: Jan 1967 thru May 1968

(4) If other information available to the planner indicates any justifiable deviation from this value, a suitable multiplier may be generated that will proportionately increase or decrease the capacities given.

3. Beaches.

a. The use of beaches as a port of entry must be considered supplementary to the use of built-up ports (SPOD), although in certain situations logistical-over-the-shore (LOTS) operations may be the only means available. The many factors that affect the capacity of the beach in LOTS, either affect SPODs to a much lesser degree or are unique to beaches alone.

b. One method of estimating capacity is to estimate the ideal condition with respect to the beach characteristics and then to degrade the estimated capacity first by the effect of natural constraints and then by the effect of operating constraints. This method is used in the following illustration of estimating beach capacity.

c. Because of the many unquantifiable factors influencing the use of beaches, no tidy formula packages have ever been developed to estimate capacity. More often than not existing beach capacity is precisely the clearance capacity because of limited surface exit routes and beach capacity is estimated by using the methods used in highway capacity estimations. On the other hand when actually using the beach considerable

effort is devoted to the continuous improvement of the surface exits, thus increasing capacity. Air exit by means of helicopters will increase the ship discharge rate and will increase beach clearance capacity if, and only if, the helicopter origin is the beach maintenance area.[3]

d. The first step in estimating capacity is to examine the beach characteristics individually. Although many are clearly interactive, the combinatorial impact is difficult to quantify. Perhaps to ignore the combinatorial effect is to err, somewhat safely, on the conservative side. The planner is encouraged to exercise his judgment in modifying the values of the individual effects of beach characteristics, weather, and operations when they are in combination since it will be perfectly clear, in most instances, what the modification should be.

e. For the overall guidance of the planner, experience has indicated that a beach will accommodate 3000 STONS of cargo per day per mile of beach — or 0.57 STONS per foot per day. On the 7900 yd OMAHA beach in WWII the maximum daily discharge was 0.63 STONS per foot, and on the 9000 yd UTAH beach the maximum was 0.35 STONS per foot — or an average maximum of 0.49 STONS per foot. The discrepancy is partially explained by the difference in exit route capacities. Similar information on beaches in the Pacific is not readily available.

f. Beach Characteristics[4].

(1) Length. By this is meant continuous usable length. This is the length in which the nearshore bottom is fairly smooth and firm, with acceptable gradients, reasonably clear of natural obstacles (underwater and ashore), and satisfactorily meeting all other requirements for a usable beach enumerated below.

(2) Width. The effective width of the beach, with respect to capacity, is called the backshore — or the distance from the limit of wave wash to the extreme limit of storm wave action. It is this area in which discharged cargo is held or in which cargo transfer takes place. Discharge is generally limited to the foreshore or the distance from low water to the limit of wave wash. On beaches with flat gradients some discharge takes place on the near shore (between low water and the

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[3]In the foreseeable future helicopter may bypass the beach by operating directly from the ship to the clearance storage area. This must be considered as a separate operation having little to do with the port/beach capacity. The capability of the helicopter fleet in STONS/day is additive — the actual port of entry is the clearance storage area and not necessarily the port/beach.

[4]FM 55-58, FM 55-50-1, FM 55-55-1.

5 fathom depth of low water) but this is generally wet discharge. Beach clearance exits beyond the backshore may have constraining capacities and may be the governing factor in estimating beach capacity (See Road Capacity Estimation). The product of length times width gives the size of the holding area, or, in other words, furnishes an estimate of the size cushion between cargo discharge and cargo clearance. Transhipment operations are generally conducted in this area. If cargo discharge is equal to, or less than, cargo clearance, this area may be utilized for purposes other than intransit storage. On the other hand if cargo discharge is greater than cargo clearance, the holding area becomes saturated and discharge operations are inevitably reduced to the level of cargo clearance. For discharge of amphibians see Hinterland (para 3f(10) which follows).

(3) Surface. The surface must be reasonably negotiable by wheeled cargo vehicles, either naturally or by artificial stabilization. This includes removal or leveling of natural obstructions. In LOTS operations negotiability may be assumed because of planned preparation. As a general rule the surface on an ocean beach may be taken as Bureau of Public Roads classification A-4 (fine sand)[5] which, when unprepared, has a factor value of 0.10 when dry, 0.25 when moist and 0.05 when wet, compared with the value of 1.00 for a concrete road. Chespaling, planking, matting, or other means of surfacing will raise these factor values to about 0.40. Silts (A4 and A5) have factor values of about one-half that of A-3.

(4) Offshore Anchorage. For large cargo ships a minimum depth of 5 fathoms (30 feet) is required to accommodate maximum draft and ground swells, and a maximum depth of 35 fathoms (210 feet) imposed by the length and weight of anchor chain. The bottom must not be too rocky or too slushy. A clear radius of at least 800 feet is necessary.

(5) Offshore routes to the beach. The route to the shore must be reasonably clear of sandbars, reefs, rocks and shoals since they may preclude the use of LCM's, LCU's, or barges, and necessitate marking, the use of amphibians, or extensive clearance. A minimum of 6 feet of water over these obstacles is necessary for amphibian operation and 11 feet for heavier landing craft. Pathces of seaweed (kelp, rockweed, sea lettuce, etc.) tend to clog propellers and cooling systems. Underwater obstructions such as these are "go, no-go" factors. These conditions tend to limit operations severely.

(6) Gradient.

(a) The following scale is customarily employed to describe beach gradients:

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[5]Or the Unified Classification SP.

Steep	More than 1:15 (one foot rise in 15 feet)	More than 7%
Moderate	1:15 to 1:30	about 6.5% to 3.5%
Gentle	1:30 to 1:60	about 3% to 1.5%
Mild	1:60 to 1:120	about 1.5% to 0.8%
Flat	Less than 1:120	less than 0.5%

(b) A gradient of 1:20 (5%) on the nearshore is considered ideal—anything less causes the craft to ground at some distance from the water line and anything more is vulnerable to heavy surf. In the latter case the steep gradient usually extends shoreward through the backshore from the water line and presents some difficulty in uphill movement. Amphibians are not affected by flat gradients alone.

(7) Surf. Surf may be caused by wind, by storms many miles offshore, by current rips, or other causes. Surf may be predictable at times or unpredictable at others. Wave motion, another contributing cause, is the composite result of many cyclic variations and has a certain predictability through the use of analyzers. Suffice to say that normal surf at a specific beach is reasonably predictable for strategic planning purposes. However vessels differ in their broaching to and swamping[6] vulnerability to surf conditions provided they are not overloaded. The following figure, derived from the data furnished in FM 101-10-1, is illustrative of the effect of surf, assuming linearity:

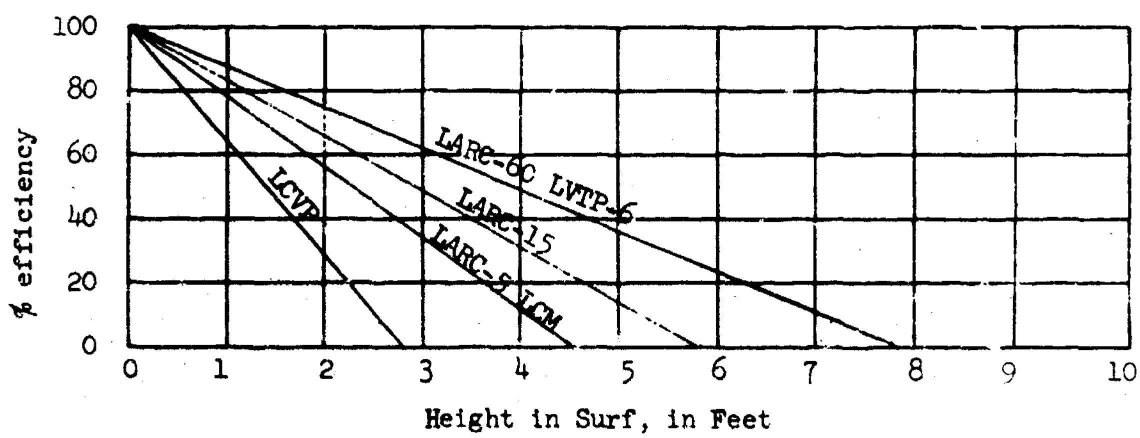

FIGURE 3. EFFECT ON SURF ON EFFICIENCY

(8) Tide. Tidal ranges are different for each prospective beach location. Although highly predictable for the normal, there are freak tides that occur infrequently. For planning purposes these latter may be ignored. Taken in conjunction with beach gradient it is possible to

[6]Swamping is rarely caused by surf alone. In many cases it is the result of improper boat handling.

plan operations to include "drying out"[7] of large vessels, provided there is a small danger of "hogging" (i.e., heavier weight of bow and stern tending to arch or "hog" the vessel's keel on certain types of beach surfaces). Tide also determines the dimensions of the backshore and the foreshore. About every 2 weeks when the moon is new or full the highest and lowest water occur (spring tides). When the moon is in the first and third quarters the tide range is smallest (neap tides). In general it is preferable to make a landing 2-3 hours before high tide where the craft may be beached and retracted readily.

(9) Current. A strong alongshore (littoral) current may be a contributing factor to broaching to of craft. Rip currents flow out from the shore in narrow bands or rips and are formed on almost all open coasts. They consist of the feeder currents (parallel to the shore inside breakers), the neck (where the feeder currents converge and flow through the breakers in a rip), and the head (where the current slackens and widens outside the breakers). Rips cut troughs in the sand and may form hazards for landing craft.

(10) Hinterland. The transportation network capacities in the hinterland behind the beaches must be sufficient to move the tonnage in the LOTS operation. This includes the exits and links connecting the exits to the main networks. If these networks have capacities below the planned discharge requirements, the network capacities may be the limiting capacity of the beach. Amphibians should discharge as close to the beach as possible, preferably not more than 6 miles for the LARC-5, 3 miles for the LARC-15, and $\frac{1}{2}$ mile for the LARC-60.

(11) Weather Effects.

(a) Wind velocity, the distance spanned by the wind, duration, and decay or attenuation distance, influence the amount of sea, swell, and surf conditions on the beach. The growth of waves, aside from cyclical influences, is governed by the velocity, duration, and area influence of wind. Swells are waves that have escaped wind influence. Less than 10 mph is considered ideal; 10 to 15 mph favorable; 15 to 25 mph difficult; and above 30 mph to tend to make operations infeasible. From this information a wind scale may be developed, assuming linearity, as follows:

[7] Beached during high tide, resting on the beach during low tide, and withdrawn in the next high tide.

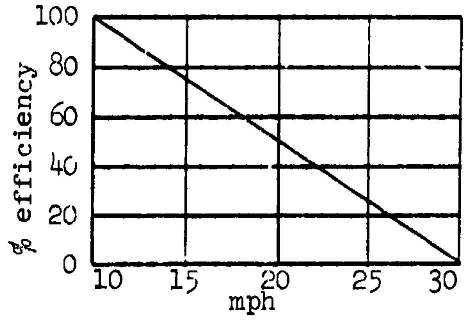

FIGURE 4. EFFECT OF WIND ON EFFICIENCY

(b) The distance at which objects can be seen in a horizontal direction at the surface may reduce or even halt operations. Visibility may be restricted by fog, haze, rain, sleet, or snow. The major effect is on offshore operations but there is also some considerable effect on clearance operations. Radar and infrared devices extend the visibility range to some extent but smaller craft are, in general, not equipped with such sensing devices. If the operator can see the destination from the origin (and vice versa) then full operations are likely. As a rule, if visibility is such that there is a possibility of collision or of getting lost then operations must be suspended. Gradations between these extremes are in a very narrow range.

(c) For planning purposes statistical studies of the area are valuable for estimating weather conditions on a probabilistic basis, including the effects of temperature and excessive precipitation. Winter weather magnifies the effect of these conditions and generally precludes beach operations.

(12) Clearance.

(a) The exits and the hinterland network are estimated by the highway and/or rail method.

(b) In the example given it is clear that the holding area is more than adequate, holding 18 times the daily discharge rate. If the exits and network can accommodate the daily discharge, then the capacity of the beach is the maximum daily discharge. If the exits are restricted then the beach capacity is the clearance capacity.

4. Recapitulation of Beach Capacity Estimation Factors.

a. The length of usable beach, in feet, when divided by the safe interval between craft (150-300 feet), gives the number of landing locations. Under favorable conditions this is 35 locations per mile and under less than favorable conditions this is 18 locations.

b. The backshore width times the length of beach is the potential storage area. The factor of 100 lbs. per square foot is an average

factor. POL and ammunition must be dispersed for safety even if there is no enemy action. Stacks for open storage are no more than 6 feet high.

c. For planning purposes, prepared beach surface has a load bearing capacity no more than 40% that of a good road. (See Highway Capacity Estimation, Chapter 4.)

d. Suitable offshore anchorage must exist in sufficient quantity to accommodate all of the vessels necessary to meet daily tonnage discharge requirements.

e. The term "usable beach" excludes those areas of underwater obstructions.

f. A gradient of 1:20 has a factor value of 1.00 for all craft. Lesser gradients do not normally impede amphibians but, in combination with the tidal range, may reduce productivity of other landing craft. On the basis of using the beaching procedure at high tides and retraction at the next high tide, productivity for the approximately 12-hour period may be limited to the load carrying capacity of the craft. Greater gradients are dangerous if accompanied by heavy surf and/or littoral current and are presumably excluded by the selection of "usable beach."

g. Surf has a more deleterious effect on amphibian operation (see surf chart) than on loading craft. A surf of over 8 feet is considered sufficient to halt operations.

h. Tide, in conjunction with fairly flat gradient as stated previously, may reduce discharge to that of the capacity of the craft for a 12 hour period.

i. Currents are either negotiable through operating skill or that portion of beach is excluded from selection of usable beach.

j. The capacity of the networks in the hinterlands may be computed by rail or highway capacity estimation. If the beach is adjacent to an inland waterway the capacity of the IWW may augment beach discharge and should be considered. However this is not part of beach capacity.

k. Wind factors are shown in the windscale chart.

l. Visibility factors, on a probabilistic basis, are obtainable from climatic briefs of the area.

m. The theoretical maximum capacity of a beach is achieved with the exclusive use of the largest landing craft.

5. Water Terminal Transportation Resources.

a. One of the determinants of port capacity is the capability of the labor force (and equipment) for cargo discharge, and for this reason a large part of the resource capability discussion was included in the previous section on water terminal capacity estimation.

b. The design capabilities of the military terminal units, as taken from the TOEs, are presented later in Table 24. Productivities of these units may vary considerably depending on the situation. One major consideration, aside from the commodity handled, is the lack of cargo to handle. For military units, present for duty under all circumstances, the zero productivity when this occurs was considered in arriving at the design capability. For civilian labor only productive time is considered; thus comparisons between civilian and military gangs frequently disparages military gang productivity. A recent study in Vietnam[8] showed 14.37 STONS per gang hour for military and 23.72 STONS per gang hour for imported Korean nationals in discharging general cargo. The comparable productivities for ammunition were 6 STONS/military gang hour and 14.17 STONS/civilian gang hour. The average productivity of the Terminal Service Company was very close to the design capability (685 to 720 STONS). The comparison is almost meaningless, not only for the above reason, but because in addition the Koreans were offered incentives and could change the composition of their gangs as necessary. This is mentioned to point out to the planner the necessity for exercising considerable judgment in assessing the productivity of host nation labor in comparing it with the productivity of military labor.

c. Furthermore the type of handling affects productivity. For example, the same study shows the difference in average military productivity as follows:

Ships hold to barge	2.35 STONS/mh	av. gang 12.9
Ships hold to vehicle	2.30 STONS/mh	av. gang 14.0
Ships hold to wharf	4.35 STONS/mh	av. gang 10.3

d. It is also pointed out that, in peacetime at least, where civilian labor productivity is controlled by labor unions, the productivity may be severely lower than the actual capability of the gangs.

e. Since staging is generally within the port complex, the staging unit capabilities are given at the end of this chapter in Table 25.

f. The elements of LOTS operations are as follows:

(1) Mix of the Landing Craft and Amphibian Fleet. This is an estimate of the capability to utilize the capacity of the beach. At

[8] Planning Research Corp., R-1240, Vol II, 1969, Development of Logistics Planning Factors in S. Vietnam, pp II 313-321 (U).

present, the landing craft fleet includes the following type craft:

Craft	Nominal LOTS Loadings (STONS)
LST	550-990
BDL	660
LCU	180
LCM	55
LCVP	4
LVTP	6
DUKW	2.5
LARC-5	5
LARC-15	15
LARC-60	60
APA	770-1650
AKA	1670-4800
AP	2350-4000
LSV	8850

Under less than favorable conditions these loadings may be reduced by as much as 50%. Ranges reflect the several designs included in the class.

(2) Lateral Safe Distances Between LOTS Vehicles. This series with wind and surf conditions and the size and type of the vehicles. For vehicles landing simultaneously FM 101-10-1 gives these distances as between 150 feet (45 meters) to 300 feet (90 meters). However, under conditions of wind and surf that are above normal, the danger of broaching to the 442' LST indicates a safe interval of at least 450' to port and starboard. After beaching (and awaiting "drying out") this interval may be reduced by smaller craft for more efficient usage of the shore. However, in the foreseeable future, the new LASH (Lighter Aboard Ship) ships with 49 to 79 lighters carrying 400 STONS each and measuring 62' long may replace the LST for this type of operation and the 150-300 foot interval comes into better perspective.

(3) Discharge and Loading Times. A terminal service company has the rated capabilities under ideal conditions of discharging 1200 STONS of general cargo or 1800 STONS of vehicles per day over the beach. Under the same conditions it can load 600 STONS of general cargo or 900 STONS of vehicles per day. The worldwide planning factor is 720 STONS discharge per day and the loading factor is 500 STONS per day because of many unpredictable conditions. These latter values are used for estimating the requirements for terminal service companies. The values for ideal conditions will be used in computing beach capabilities to avoid double correction (as will be shown). Loading time is thus 30 STONS/hour and discharge 60 STONS/hour for a 20 hour day.

(4) Transhipment Time. The terminal transfer company has three operating platoons each capable of transhipping an average of 300 STONS per day. The company can thus tranship 45 STONS/hour.

(5) Turnaround Time. This is computed for amphibians from the following formula:

$$T = \frac{2D_w \times 60}{S_w} + \frac{2D_l \times 60}{S_l} + T_1 + T_2 + D$$

where
T = turnaround time, in minutes
D_w = water distance, one way, in miles
D_l = land distance, one way, in miles
S_w = water speed, in mph (average 8 mph)
S_l = land speed, in mph (average 20 mph)
T_1 = loading time, in minutes (1 STON per 5 minutes)
T_2 = discharge time, in minutes (2 STON per 5 minutes)
D = delay, in minutes

(6) Craft Availability Factor. Usually taken as 75% of total number of craft.

(7) Craft Requirements, Total Daily Cargo.

$$L = \frac{C}{V \times \frac{T_3}{T}}$$

where
L = craft requirements (75% of total)
C = cargo total tonnage, in STONS
V = average load, in STONS
T_3 = operational time, in minutes
T = turnaround time, in minutes

(8) Craft Requirement, Per Hatch

$$L = \frac{T}{R}$$

where

$$R:\ \text{MAX} \begin{vmatrix} T_1 \\ T_2 \\ D \end{vmatrix} = \text{most restrictive factor}$$

(9) Tonnage Capabilities of a Fleet

$$TC = \frac{T_3 \times V \times L}{T}$$

where TC = Tonnage capabilities of a fleet
V = tonnage per lighter
L = number of lighters

6. Computations.

a. The LST carrying an average loading of 600 STONS will be used to illustrate the capacity formulation. The LARC-15 (15 STONS) will be used to illustrate the derivation of capacity using amphibians exclusively. Availability of sufficient craft is assumed.

b. Discharge on the beach is at the ideal rate of 60 STONS/hour per terminal service (TS) company. Transhipment from ship to lighter is 30 STONS/hour per company. Transhipment from amphibian to truck or from holding area to truck is 45 STONS/hour per terminal transfer company.

(1) Beach holding area capacity

$$\frac{B \times W \times 100}{2000} = \text{Capacity} = BC(\text{STONS})$$

where B = Length of usable beach, in feet
W = Width of beach, in feet
100 = pounds per square foot
2000 = pounds per STON

For example: B = 5280 feet
W = 200 feet
BC = Capacity of holding area

$$BC = \frac{5280 \times 200 \times 100}{2000}$$

BC = 52,800

(2) Fleet discharge per mile

Beach capacity, per mile =

$$D \times V \times F_1 \times F_2 \times F_3 \times \min\left|\begin{matrix}F_4\\F_5\end{matrix}\right. \times F_6 \times N$$

where N = number of landing locations per mile
D = utilization (craft per 20 hour day) = $\dfrac{20 \times 60}{\text{Turnaround time, T, in minutes}}$
V = average load, in STONS
F_1 = surf factor

F_2 = wind factor

F_3 = gradient factor

F_4 = visibility factor

F_5 = weather factor

F_6 = reduction factor to avoid queues

(3) For example:

D = 1.10 (for LST), 12.0 (for LARC-15)
V = 600 STONS (for LST), 15 STONS (for LARC-15)
N = 18 (for LST), 35 (for LARC-15)
F_1 = 0.5

F_2 = 0.8

F_3 = gradient of 1:20 = 1.00

F_4 = probability of good visibility = 0.9

F_5 = spring, probability of good weather = 0.83

F_6 = 0.86

(4) Then, Beach Capacity per mile =

1.1 x 600 x 18 x 0.5 x 0.8 x 0.83 x 0.86 =

3392 STONS/day (using LST's)

12.0 x 15 x 35 x 0.5 x 0.8 x 0.83 x 0.86 =

1799 STONS/day (using LARC-15's)

TABLE 24. TERMINAL AND WATER TRANSPORTATION UNITS

Unit	TOE	Mission	Capability
Transportation Terminal Service Company	55-117G	To load, unload, or transship from one to another means of transportation (water, rail, air highway) at terminals and over-the-shore facilities.	At full strength operating on one ship on a two-shift basis, or on two ships on a one-shift basis, at piers or over beaches, can discharge 720 STONS of cargo per day, or can load 500 STONS of cargo per day.
Transportation Terminal Transfer Company	55-118G	To transship cargo at Army air, rail, motor, and inland barge terminals.	At full strength, this unit is capable of: (1) transshipping 900 STONS of cargo daily, (2) operating at three separate terminals on an around-the-clock basis.
Transportation Medium Boat Company	55-128G	To provide and operate landing craft for the movement of personnel terminal operations and to augment, when required, naval craft in joint amphibious operations.	At full strength, this unit is capable of: (1) transporting an average of 720 STONS of general cargo daily in logistics-over-the-shore (LOTS) operations, based on an average load of 30 STONS per each of 12 landing craft making two trips daily, (2) transporting, in a one-time maximum lift, 960 STONS of general cargo based on 16 landing craft, (3) transporting, in a one-time maximum lift, 3,200 combat-equipped troops based on 16 landing craft.

TABLE 24. TERMINAL AND WATER TRANSPORTATION UNITS (CON)

Unit	TOE	Mission	Capability
Transportation Heavy Boat Company	55-129G	To provide and operate landing craft for transporting personnel and heavy cargo in offshore discharge operations and for augmenting lighterage service in a port or harbor in inland or coastal waters or on the open sea including lighterage service required in joint amphibious or other waterborne tactical operations.	(1) Transporting per trip an average of 1,440 STONS of general cargo, daily in LOTs operations, or 4,000 troops with individual equipment, or 540 STONS of vehicles, or 1,500 STONS of tanks, based on availability of 10 landing craft. (2) Transporting, in a one-time maximum lift, 1,800 STONS of general cargo, or 4,800 troops with individual equipment, based on availability of 12 landing craft, each capable of transporting 150 STONS of cargo or 400 troops for a trip not exceeding 2 hours. (For trips in excess of 2 hours, but less than 3 hours, the maximum troop lift is 4,200 and over 3 hours the maximum is 3,600.)
Transportation Light Amphibian Company	55-138G	To provide lighterage for movement of cargo and personnel between ship and shore, in an amphibious or logistical operation.	(1) Transporting daily, operating around-the-clock, 1000 STONS of general cargo per day, assuming availability of 25 LARCS, each LARC carrying 2.5 STONS of cargo per trip and averaging 16 trips per day. For world-wide planning purposes 720 STONS should be utilized.

TABLE 24. TERMINAL AND WATER TRANSPORTATION UNITS (CON)

Unit	TOE	Mission	Capability
Transportation Medium Amphibian Company	55-139G	To provide lighterage for the movement of cargo from ships lying offshore to transfer/segregation points beyond the beach line in LOTS operations and in support of amphibious operations.	1. Transporting daily, operation two 10-hour shifts, an average of 1,050 STONS of general cargo per day assuming availability of 19 lighters, each lighter carrying approximately 10.2 STONS per trip and averaging 5 to 6 trips per day.
Deck Cargo Barge Crew, Non-propelled (team FA)	55-530G	To transport dry deck cargo.	Transporting 105 STONS of deck cargo at 4 knots.
Deck or Liquid Barge, 120 ft, Non-propelled (team FC).	55-530G	To crew barge and provide pump operations and lighterage for bulk liquid cargos in waterway operations; barge is capable of transporting cargo on deck.	When under tow, capable of lightering up to 4160 bbls of liquid cargo or up to 655 STONS of dry cargo on deck.
Refrigerator Barge Crew, Non-propelled (team FF)	55-530G	To transport refrigerated cargo.	Transporting 355 STONS of refrigerated cargo at 4 knots.
Liquid, dry or refrigerated cargo barge, 216 ft, SP (team FL)	55-530G	To provide crew and vessel for transport of liquid, dry or refrigerated cargo in terminals or along coast-wide routes not otherwise served by MSTS.	(1) Capable of lightering or transporting in coastwise traffic, 11,000 bbls of liquid cargo in a single lift or; (2) capable of transporting 1,000 STONS of refrigerated cargo in a single lift or 1,000 STONS of dry cargo.

TABLE 24. TERMINAL AND WATER TRANSPORTATION UNITS (CON)

Unit	TOE	Mission	Capability
Beach discharge lighter (team FM)	55-530G	To transport large quantities of mobile and/or out-sized equipment and unitized cargo from ships standing off-shore to undeveloped beaches.	Marrying with and discharging an ocean roll-on/roll-off vessel where port facilities for the RO/RO vessel are not available.
Lighter amphibious LARC LX (team FN)	55-530G	To provide amphibious lighterage services primarily for items of heavy, outsize or bulky equipment.	Transporting daily, oper[illegible]ng two 10-hour shifts, 450 S[illegible] heavy outsizes or bulk[illegible]ment (based on 75% availability of four LARC's LX's each making 5 trips per day carrying 30 STONS per trip). Each LARC LX has a rated capacity of 60 STONS or 125 combat equipped troops.

TABLE 25. STAGING AND REPLACEMENT UNITS

Unit	TOE	Mission	Capability
Adjutant General Repl Co.	12-57C	To provide the operating component of the replacement system for messing, billeting, limited equipping, locally controlling and orienting replacements.	Provides messing, billeting, and limited training for 400 replacements when organized at full strength. (1) Replacement capability per month at the average of 48 hours per replacement--6,000. (2) Stockage capability per month at the average of 144 hours per replacement--2,000.
Transportation Staging Area Co.	55-147D	To provide mess and billeting facilities to transient troop units and transient personnel at water terminal or at terminal locations on lines of communications.	a. Provides mess and billeting facilities for 7,500 troops in the units daily. b. When operating at any of the 5 dispersed staging areas (3 at reduced strength), each detachment is capable of providing mess and billeting facilities for an infantry brigade, or equivalent (1,500 troops). c. When operating along lines of communications or providing mess and billeting facilities for transient personnel, necessary kitchen and labor personnel must be furnished from TOE 29-500D and 10-500D.

CHAPTER 9. AIR TERMINALS

1. Airfield Capacity Estimation.

a. Except for certain emergency conditions, logistical airlift in wartime is always in competition for space with either tactical aircraft at military fields or commercial aircraft at commercial airfields. Furthermore, the airfields may only be used by airlift aircraft whose characteristics are compatible with those of the airfields.

b. Generally speaking, the largest and/or most productive aircraft accommodated by the field is used in estimating capacity, on the assumption that all aircraft lesser than this can also be accommodated. Cargo handling and beddown space available is seldom used optimally because the exact mix of aircraft making maximum use of this space occurs only by chance.

c. Lastly, cargo handling crews are designed for the sustained daily workload, not the maximum, and a queue is inevitable if the arrival rate equals or exceeds the service rate. Thus the sortie rate must be controlled because of space handling considerations.

d. The first step in capacity estimation is to determine the type aircraft that may use a specific field. This is done by comparing the runway length, width, and bearing capacity of the field in equivalent single-wheel loads (ESWL) with the similar characteristics of the aircraft. Navigational aids at the field must be adequate for the type aircraft. Aircraft not accommodated by the field are eliminated from consideration.

e. The next step is the determination of space available. Total usable parking space is first computed. The space requirements of the units stationed at a military field, or routine users of commercial fields, are deducted from this total and the result is the residual space candidate for airlift aircraft. The requirements for space for host aircraft is not easy to compute. Not only must they have parking (beddown) space, but loading and service space as well -- and this varies with the type unit and its mission responsibilities. It must be expected that in operation these space requirements will vary from time to time and even from day to day, resulting in sizable variations in space available for airlift.

f. The next step is to devise a plan for the utilization of the allotted space. This is based on space requirements of the mix of individual aircraft, and the ground time and the authorized cabin load (ACL) of each. The parking space required for an aircraft = length x

width x 3.5. The 3.5 takes care of wing up clearance, taxi lanes, and service alongside.

g. From these data and the number of operating hours (determined by lighting, navigation aids, and personnel availability) the number of sorties may be computed and the tonnage capacity estimated.

h. Using the residual space as the point of departure, then, for the i^{th} type aircraft:

$$\frac{P}{P_i} \times \frac{h}{g_i} = A_i$$

where P = residual space, in ft^2

P_i = beddown space required by i^{th} type aircraft, in ft^2

h = airfield hours of operation per day

g_i = average ground time for i^{th} type aircraft, in hours

A_i = maximum sorties of i^{th} type aircraft, per day

and $l_i\ A_i = L_i$

where l_i = payload (ACL) of i^{th} type aircraft

L_i = maximum daily delivery of the fleet of i^{th} type aircraft

and $\max L_i$ = theoretical logistical capacity of the field in STONS for the i^{th} type aircraft

with the corresponding

$\max A_i$ = theoretical logistical capacity of the field in airlift sorties for the i^{th} type aircraft.

i. Obviously, the capacity of the field is dependent on the mix of aircraft using it. By computing sorties and capacities for a pure fleet, the maximum delivery and number of sorties may be obtained by comparison, or the capacity may be given for each type aircraft assumed as sole users. One gross method, for planning purposes, is to take the aggregated capacities of all airfields in the objective area divided by the aggregated space-hour demands of the available fleet and the result proportioned to the individual airfields by the percentage of the total capacity contributed by the individual airfield.

j. Practically, the theoretical capacity where the arrival rate = the service rate, inevitably leads to a queue, even though each flight may be scheduled. It has been determined that the probability of a queue forming is very low when a random arrival rate is 80% of a

random service rate. Departures from schedule during wartime are far from rare and the adoption of the rule that the practical capacity is 80% of the theoretical tends to minimize the threat of a queue.[2] Furthermore, this reduction will also tend to absorb the combinatorial effects of the variable mix of aircraft arriving daily, each type with differing characteristics.

k. Average productivity is a function of many variables, included among which are:

(1) Capacities and aggregated residual capacities of all airfields in the objective area, including airfield closings and openings.

(2) Delivery priorities at specified airfields.

(3) Size and composition of the airlift fleet, by type aircraft:

(a) Numbers

(b) Parking demands

(c) Payloads (ACL)

(d) Time on ground

(e) Utilization rates

(f) Availability rates

(g) Attrition, replacement, and augmentation

(h) Stowage factors

(i) Block speeds

(j) ESWL

(4) Availability of cargo at origin

(5) Adequacy of unloading and clearing resources

(6) Weather factors

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[2] Sorties may also be limited by other than space consideration, e.g., tactical traffic may be such that the number of airlift sorties permitted is much less than indicated by the residual space. Thus the capacity must be reduced accordingly, or the type aircraft delivering the maximum tonnage for the number of sorties permitted be used exclusively and capacity obtained in this manner.

(7) Adequacy of lighting and navigational aids

(8) Airfield hours of operation

(9) Sorties permissible

(10) Optimum allocation of aircraft

(11) Consideration of largest aircraft accommodated by the airfield.

(12) Round trip and critical leg distances

(13) Air superiority

(14) Airfield damage control

(15) Requirements at airfields and the objective area

l. It is definitely possible that in given situations productivity at any airfield may exceed the rated capacity. It is also possible that an airfield productivity seldom attains the rated capacity.

m. The capacity of the airfields in the data base, in sorties per day, was obtained from several sources that are indicated in each table. Care must be exercised in their use since the distribution of tactical units may influence the amount of residual space allotted to airlift at specific airfields.

2. Air Terminal Mobility Support Resource Requirements.[3]

a. Joint regulations AR 59-106-AFR 76-7 assign responsibilities and functions in connection with the operations at air terminals. The Air Force and the Military Airlift Command (MAC) use units tailored to the exact requirements for loading-unloading at specific terminals. The three types of air terminals and the support forces at each are:

(1) Aerial Ports of Embarkation/Debarkation (APOE/D). These terminals are usually supported by MAC aerial port squadrons or detachments, equipped in accordance with the specific workload. The special purpose materials handling equipment normally used is part of the 463L system developed by the Air Force. All MSF are designed to reduce aircraft (a/c) turnaround time to the minimum.

[3] JR, AR 59-106 and AFR 76-7.

(2) Tactical (Intratheater) Air Terminals.

(a) These terminals are less sophisticated and the equipment is predominantly oriented to the C-130 a/c. Terminal support is furnished by an Air Force Aerial Port Squadron or Detachment or cellular fragments thereof.

(b) The TAC Aerial Port Squadron is not comparable to a MAC operated terminal as the mission of each is quite different. The TAC operated terminal is more of a transshipment terminal handling both inbound and outbound cargo. A wide variety of cargo, both large and small, is handled and it is generally in direct support of Army ground forces forward of a fixed base. The squadron also provides Combat Control Teams (CCT) in support of the Army and is required to set up drop zones (DZ), landing zones (LZ), and extraction zones (EZ) in combat areas. Further, the squadron also provides air traffic control facilities in combat zones as well as a point-to-point HF communications net for command and control. This squadron, with its CCT, is capable of operating at several locations simultaneously with small tonnage capacities in support of Army operations. The squadron is composed of 10 officers and 209 airmen plus a CCT of 4 officers and 44 airmen. At one location, on a 24-hour basis, day in and day out, it has a 450 STONS/day throughput capability (450 STONS inbound and 450 STONS outbound) or 900 STONS/day handling capability. It can peak and handle a much higher tonnage for a 48-hour period but production would be lessened after that time until personnel are rested. Typical MHE and vehicles authorized are as follows:

- Air Transportation Terminal Trailers
- Rough Terrain Loaders
- 10K Heavy Duty Fork Lift
- 6K Fork Lift
- 10K Fork Lift
- 25K Loader
- Pallet Trailer
- 2½-ton Truck
- 5-ton Tractor
- 40 ft Trailer
- Wrecker, 5-ton

(3) Forward Air Strips. These terminals are in the Army forward areas and may be supported by AF Aerial Support Detachments or cells, or by Army units. The equipment is for rough terrain and is designed to load-unload helicopters, C-7s, or C-130s.

b. Manpower. Under peacetime conditions the aerial port squadron man will have 140 productive hours and handle 43 STONS per month. In war the man will have 220 productive hours and handle 71 STONS per month (2.4 STONS/day/man).

c. Facilities.

(1) Passenger -- 50 sq.ft. each for first 500 passengers per day. 20 sq. ft. for each passenger over 500.

(2) Freight -- 320 sq. ft. per ton for processing; 120 sq. ft. per ton for marshalling of two-day backlog.

(3) Covered space requirements for freight is based on approximately 1/3 of the total freight space required.

d. Materials Handling Equipment (MHE).

(1) Cargo Processing.

(a) Pallet Docks

50 to 199 tons per day = 75' of docks
200 to 399 tons per day = 300' of docks
400 to 999 tons per day = 600' of docks
1000 to 1499 tons per day = 900' of docks
1500 to 2500 tons per day = 1200' of docks

(b) Pallets

Basic allotment of 32 pallets (required to turn a C-5 around).

One days average tonnage divided by 2.5 tons (average pallet weight) provides station pallet allotment.

(c) Pallet Dollies and/or Pallet Trailers (R/T)

Basic allotment of 32 units.

One days average tonnage divided by 2.5 tons (average pallet weight) provides the station allotment.

(d) Forklifts, 6000# (463L and/or standard)

50 to 299 tons per day = 3 forklifts

One additional authorized for each additional 300 tons or a portion thereof.

(e) Forklift, 10,000# (463L standard and/or 463L rough terrain)

50 to 5[illegible] tons per day = 3 forklifts

One additional for each additional 300 tons per day or a portion thereof.

(2) Flight Line Loading Equipment Allocation Standards.

(a) Forklifts 6000# (463L standard and/or 463L rough terrain).

One per C-7 type aircraft being worked simultaneously with minimum allocation of two per terminal.

(b) Forklifts 10,000# (463L standard and/or rough terrain).

One per 463L equipped aircraft being worked simultaneously with minimum of two per terminal.

One additional for C-5A, C-141, CL-44, DC-8F, B-773 or similar sized aircraft being worked simultaneously with other aircraft.

(c) Aircraft Loader, 10,000# rough terrain. One per each five pallets being handled on or off an aircraft simultaneously where operating surfaces preclude the use of 25K or 40K loaders.

(d) Aircraft Loader, 20,000# (20K).

Two per first 15 pallets being worked on or off aircraft simultaneously.

One additional for each three pallets being handled on or off an aircraft simultaneously.

(e) Aircraft Loader, 40,000# (40K).

Two per first 20 pallets being worked on or off an aircraft simultaneously.

One additional for each additional five pallets being worked on or off an aircraft simultaneously.

(3) Other Required Specialized Equipment Allocation Standards.

(a) Ramp Kit (C-130) -- Two per terminal and two per each mobility team.

(b) Tugs, Warehouse -- Two per each 250 tons or a portion thereof handled per day.

(c) Trailers, Baggage -- Three per each tug (or substitute) authorized.

(d) Floodlight Unit, portable, self-powered.

Two per terminal and two per each mobility team.

Two additional for each working area without fixed flood lighting.

(e) Trailer, Lavatory Servicing.

Two per terminal handling recurring strategic airlift passenger flights.

One additional for each strategic airlift passenger flight over the basic two being worked simultaneously.

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Enclosure 1

ENCLOSURE 2. GLOSSARY OF TERMS

Accompanying Supplies. All classes of supplies carried by units into the objective area. (JCS Pub. 1, AR 320-5)

Advance Logistical Command. A command normally located in the forward portion of the communications zone of a theater of operations, responsible for furnishing administrative support, except personnel replacement, civil affairs, and intersectional services, to forces in the combat zone as directed. (AR 320-5)

Advanced Base Functional Component. A grouping of personnel and/or material designed to perform one of the specific tasks of an advanced base. A functional component contains the technical personnel and equipment necessary for the performance of their tasks, including, as pertinent, workshop housing, vehicles, boats, shop and office equipment and a 30-90 day initial supply of consumables. The functional components are given titles to indicate their functions and unclassified codes each consisting of an alphabetic/numeric combination. (BUWEPSINST 4040.1)

Aerial Port. A facility located on an air base, consisting of one or more air terminals, and constituting an authorized port of entry to and clearance from a country. (AR 320-5, JCS Pub. 1)

Aerial Port Squadron. An Air Force organization which operates and provides the functions assigned to aerial ports to include the processing of personnel and cargo, rigging for airdrop, packing parachutes and loading equipment, preparing air cargo and load plans, loading and securing aircraft, ejection of cargo for inflight delivery, and supervision of units engaged in aircraft loading and unloading operations (JCS Pub. 1, AR 320-5)

Air Freight Terminal. A facility which provides administrative functions and space for intransit storage: the receipt and processing originating, terminating, and intransit air cargo; and the marshalling, manifesting, and forwarding of air cargo to destination of either domestic or oversea bases. (AFM 11-1)

Airfield. An area prepared for the accommodation, (including any buildings, installations, and equipment), landing and taking-off of aircraft. (JCS Pub. 1)

Airhead. A designated location in an area of operations used as a base for supply and evacuation by air (JCS Pub. 1)

A designated area in a hostile or threatened territory which, when seized and held, insures the continuous air landing of troops and materiel and provides maneuver space necessary for projected operations. Normally, it is the area seized in the assault phase of an airborne operation. (JCS Pub. 1)

Airlift. The carriage of personnel and/or cargo by air. (JCS Pub. 1)

To transport passengers and cargo by use of aircraft. (JCS Pub. 1)

The total weight of personnel and/or cargo that is, or can be carried by air, or that is offered for carriage by air. (JCS Pub. 1)

Alinement, wharf. Angle points, indentations, or curvatures existing along the face of a wharf.

Alongside. Adjacent to the head or face of a pier or to the side of a pier or vessel; usually indicating a parallel arrangement.

Ammunition and explosives. Bombs fuses, TNT blocks, caps, handgrenades, powder, dynamite, or any other commodity which must be allocated isolated and specialized stowage space in a cargo ship or be carried in an ammunition ship or be loaded and discharged at an ammunition pier because of its highly explosive nature. Does not include small arms ammunition.

Anchorage. That portion of a harbor in which ships are permitted to lie anchored so as not to interfere with harbor traffic, cables, or pipeline crossings, etc. Normally, the anchorage space assigned to a vessel must include a circle of which the combined length of anchor chain and ship is the radius.

Approach root. The shore end of a platform used in transporting cargo between the shore and an off-shore wharf strucutre.

Apron. That portion of a wharf or pier lying between the waterfront edge and the (transit) shed. Strictly speaking, from the viewpoint of construction, that portion of the wharf carried on piles beyond the solid fill. Also called "Apron Wharf" and "Wharf Apron".

Army Wholesale Logistics. The Army Logistics System less army in the field logistics; includes complete logistic support of the Army Wholesale Logistics complex itself, and of special Army activities retained under direct control of Headquarters, Department of the Army. (AR 320-5)

Army Wholesale Materiel. Army Wholesale Logistics less the services activities (communications, construction, hospitalization and evacuation, and support services) retained at the Department of the Army level and logistics support of special Army activities retained under direct control of Headquarters, Department of the Army. (AR 320-5)

Automatic Supply. A system by which certain supply requirements are automatically shipped or issued for a predetermined period of time, without requisition by the using unit. It is based upon estimated or experience-usage factors. (JCS Pub. 1, AR 320-5)

Available Equipment. Available equipment is any end item of equipment which is physically on hand within an organization and does not meet the criteria for being classified as nonavailable. (TM 38-750)

Availability (Equipment). The fraction of the total desired operating time that material actually is operable. (NAVAIRINST 47002)

Aviation Fuel. Gasoline grades 115/145, 110/130, and 91/96, and jet fuel grades JP-4 and JP-5. (AR 320-5)

Barge. A floating craft of full body and heavy construction, designed for carrying cargo. Cranes or other cargo handling gear are often mounted on barges. (The distinction between a barge and a lighter is more in the manner of use than in form and equipment, the term barge being more often used when the load is carried to its destination, or a long distance, while the term lighter refers to a short haul, generally in connection with loading or unloading operations of deeper-draft vessels).

Barge Tow. A group of one or more barges and a powered craft such as a tug, towboat, pushboat or self-propelled barge.

Barrel. A measure of the volume of liquid petroleum products equal to 42 U.S. gallons at 60°F. Not to be confused with drum. See Drum.

Base Depot. Supply point in a communications zone in a theater of operations. (AR 320-5)

Base terminal. A base terminal is the upstream or initial storage terminal of a pipeline, usually at or near a port of entry from which a pipeline system originates.

Basin. A large slip or dock partially surrounded by quays.

Beach Capacity. An estimate, expressed in terms of measurement tons, or weight tons, or vehicles, of cargo that may be unloaded over a designated strip of shore per day. (JCS Pub. 1)

Beach Support Area. The area to the rear of a landing force or elements thereof, established and operated by shore party units, which contains the facilities for the unloading of troops and materiel and the support of the forces ashore; it includes facilities for the evacuation of wounded, prisoners of war, and captured materiel. (JCS Pub. 1)

Berthing space. The water area fronting a wharf or mooring at which inland waterway craft may load or discharge cargo. Wharfage is usually expressed in terms of linear feet.

Boat space. The space and weight factor used to determine the capacity of boats, landing craft and amphibious vehicles. With respect to landing craft and amphibious vehicles, it is based on the equipment.

A man is assumed to weigh 224 pounds and to occupy 13.5 cubic feet of space. (AR 320-5)

Branch station. A pumping station on a branch pipeline taking off from a mainline to supply an airfield or other large consumer that cannot adequately or conveniently be supplied from an intermediate supply point on the main line.

Break Bulk Point. A transshipping activity to which unitized shipment units for various ultimate consignees may be consigned for further distribution as separate shipment units. (DOD 4500.32-R)

A transshipping activity to which multiple shipment units may be consigned for further distribution within the transportation system. (AR 320-5)

Bulk Cargo. Dry or liquid cargo such as oils, coal, grain, ore, sulphur, fertilizer, etc., that are shipped unpackaged and usually in large quantities. (DOD 4500.32-R)

Bulk Load Method. In airborne usage, the bulk load method is generally used for computing aircraft requirements to transport bulk supplies. The method is based on the fact that the weight of the cargo is the determining factor in computing aircraft requirements. (AR 320-5)

Bulk Materials. Those necessary constituents of an assembly or subassembly such as oil, wax, solder, cement, ink, damping fluid, grease, powdered graphite, flux, welding rod, thread, twine, chain, etc. for which the quantity required is not readily predeterminable: or if knowing the quantity, the physical nature of the material is such that it is not adaptable to depicting on a drawing; or which can be cut to finished size by the use of such hand or bench tools as sheers, pliers, knives, etc., without any further machining operations and the configuration is such that it can be fully described in writing without the necessity of pictorial presentation. (MIL-D-70327, NAVAIRINST 4700.2)

Bulk Petroleum. Liquid petroleum products which are normally transported by pipeline, rail tank car, road tank truck, road tank trailer, barge, harbor or coastal tanker and ocean going tanker and stored in a tank or container having a fill capacity greater than 55 US gallons (45 Imperial gallons). In the context in which it is used in this definition, "petroleum" also covers products which are generally similar to petroleum products but which have different bases. (AR 320-5)

Bulk Supply. Any kind of military supplies that are sent out in very large quantities. Sand, gravel, paint, gunpowder, etc., are examples of bulk supply. Bulk supplies are measured in terms of weight or volume rather than in terms of the number of units. (AR 320-5)

Capability. The practical maximum amount of cargo, expressed in tons per day, that may be handled on a continuing basis by given transportation resources when the limitations of the major contributing factors are considered to a practical degree.

Capacity. The theoretical maximum amount of cargo, expressed in vehicles or tons per day, that may be handled on a continuing basis by a given facility or transportation mode link, with all contributing factors, such as facilities, personnel, and weather introduced into the system to an optimum degree.

Cargo. Includes all items of supplies, materials, stores, baggage, or equipment which are classified and transported as freight in contrast to those items which are classified and transported incidental to passenger movements. (DOD 4500.32-R)

Channel Airlift. Common-user airlift service provided on a scheduled basis between two points. (JCS Pub. 1, AR 320-5)

Channel Traffic. The movement of personnel and cargo over established world-wide routes, serviced by either scheduled military aircraft or commercial aircraft under contract to and scheduled by MAC. (DOD 5160.2)

Traffic moved between established aerial ports of embarkation and debarkation of MAC scheduled flights. (DOD 4100.31)

Characteristic. A segment of a functional area subject to analysis or review. Characteristics may be reviewed by statistical sampling or by other means. (AFSCM 78-1)

Chart datum. The datum to which soundings on a chart are referred. It is usually taken to correspond to a low-water state of the tide.

Civil requirements. Regulations governing commercial shipping and cargo handling in the port. Usually under the jurisdiction and enforcement of the port authority.

Civil Reserve Air Fleet. A group of commercial aircraft with crews which is allocated in time of emergency for exclusive military use in both international and domestic service. (JCS Pub. 1)

Aircraft owned and operated by private industry which are convertible to government use on a contract basis in time of emergency to insure immediate and continuous logistical support in wartime. (AFM 67-1)

Transport aircraft of commercial air carriers which, under the Emergency War Plan, have been allocated to the Department of Defense by the Department of Commerce to augment the MAC fleet. (DOD 4100.31)

Civilian Supplies. Commodities, goods or services made available to the civilian population, government or economy in areas administered by armed forces. (AR 320-5)

Classification Yard. A group of railroad tracks used for receiving, shipping and switching rail cars. (AFM 11-1)

A network of railroad tracks where cars of incoming trains are separated and reformed into new trains preparatory to dispatch over separate outgoing lines. (AR 320-5)

Clearance Capacity. An estimate expressed in terms of vehicles or weight tons per day of the cargo that may be transported inland from a beach or a port over the available means of inland communication, including, roads, railroads, and inland waterways. The estimate is based on an evaluation of the physical characteristics of the transportation facility in the area. (JCS Pub. 1, AR 320-5)

Combat Service Support Elements. Those elements whose primary missions are to provide service support to combat forces and which are a part, or prepared to become a part, of a theater, command or task force formed for combat operations. (AR 320-5, JCS Pub. 1)

Commercial Transportation. Transportation commercially owned and operated, such as buses, streetcars, trains, subways, taxicabs, boats, or other mode with fares or tokens furnished or paid by the Government. (AR-55-34)

Commodity. A grouping or range of items which possess similar characteristics, have similar applications, or are susceptible to similar supply management methods. (DOD 5000.8, AFM 67-3/AFLC Sup 1, AFM 67-1)

Construction Materials. Construction materials means articles, materials, and supplies, which are brought to the construction site for incorporation in the building or work. (ASPR 18-506.2)

Container. A box used to consolidate shipments, preserving the integrity of the shipment against pilferage and the effects of the elements. Military containers of the CONEX variety are examples. Commercial containers may carry cargo up to 40 STONS.

Contract, Shipping. Shipping contracts are executed between the Military Sea Transportation Service and commercial ocean common carriers providing for ocean transportation of cargo at special rates, usually on regularly scheduled ships operating on established trade routes. Shuch contracts provide that stevedoring services are to be performed during overtime hours at the request of the carrier, all terminal overtime differential costs required to support the operation are for the account of the carrier. (DOD 4500.32-R)

Controlling Depth. Controlling depth is the minimum depth which can be expected at a specified datum level; usually a low water datum or chart datum level. Note: Occasionally during extreme tidal conditions, the water level could conceivably fall below that level which is indicated as a controlling depth.

Convoy. A number of merchant ships or naval auxiliaries, or both, usually escorted by warships and/or aircraft, or a single merchant ship or naval auxiliary under surface escort, assembled and organized for the purpose of passage together. (AR 320-5)

A number of vehicles travelling as a unit or set of units under military control.

Craft Capability. The amount of cargo expressed in sized barges or tons per day that may be moved by a given number of inland waterway craft on a continuing basis, exclusive of any restrictions imposed by the terminal facilities.

Datum Plane. A plane used as a reference from which to reckon heights or depths. A plane is called a tidal datum when defined by a certain phase of the tide. The datum may be based on mean sea level, but for hydrographic work, including soundings on charts and tidal predictions, a low-water datum is usually perferred.

Deadlined Equipment. Any major end item of authorized equipment charged to a using unit or agency which has been removed from operation or immediate operational readiness because of actual or potential mechanical, electrical or safety device failure. It does not include equipment scheduled for routine preventive maintenance or inspection. (AR 320-5)

Deadlining Loss (waterways). Amount of inoperable inland waterway craft, usually expressed in percentage of total cargo carrying tonnage for cargo carrying craft, and in number of units for towing craft.

Dead Weight Cargo. Those commodities having a stowage factor less than 40 cu. ft. per ton of 2,000 lbs., or 2,240 lbs. as the custom of the service (trade) may be.

Dead Weight Carrying Capacity. The difference in tons of 2,240 lbs, between the displacement of the ship when light and when fully loaded to the maximum draft allowed by law. In other words, dead weight carrying capacity is the weight in long tons of cargo, fuel, water, stores, crew, passengers, and their effects, that can be carried safely by the ship. It is usually about two-thirds of the displacement tonnage and 2 1/3 to 2 3/4 times the net registered tonnage; theoretically as 40:100.

Depot. A facility for the receipt, classification, storage, accounting, issue, maintenance, procurement, manufacture, assembly, research or salvage of supplies, or for the reception, processing, training, assignment, and forwarding of personnel replacements. It may be an installation or activity of the zone of the interior or area of operations. (JCS Pub. 1)

Direct Support. A mission requiring a force to support another specific force and authorizing it to answer directly the supported force's request for assistance. (JCS Pub. 1)

Diurnal Tide. Having a period or cycle of approximately one lunar day. Thus, the tide is said to be diurnal when there is a single flood and a single ebb period in the lunar day.

Downtime. That portion of calendar time during which the item is not in condition to perform its intended function. (NAVAIRINST 4700.2)

Time during which any material that is not available for use because of maintenance requirements. (AR 320-5)

Interval between receipt of a request for supplies at a supply depot and their delivery to the troops. (AR 320-5)

Interval between the arrival of an empty ammunition train at an ammunition supply point and its departure with a load. (AR 320-5)

Driveaway Service. The transporting or moving of a vehicle under its own power by a driver furnished by an authorized commercial motor carrier. This method also includes the movement of one or more vehicles including other than self-supported vehicles when towed or mounted (either full or saddle mount) upon a vehicle moving in driveaway service. (DSAR 4500.3)

Drum. Container, usually of metal, for fuels. Most common capacities in Army use are 5 gallons and 55 gallons. Five-gallon drums are usually referred to as cans.

Dumb Craft. Inland water way craft which have no self-contained means of propulsion.

Dunnage. Loose material used around cargo to prevent damage.

Emergency Head Capacity. Pressure in feet of head which a pumping unit produces at maximum rate of discharge.

Facilities. Buildings, structures, or other real-property improvements as separately identified on the real-property records, including items of real-property installed equipment attached to or installed in real property. (AFSCM 375-5)

An element of integrated logistic support, consisting of physical plants such as real estate and improvements thereto, including buildings and associated structual equipment and utilities which

are required for or contribute to support of the systems, subsystems, or equipments. (DOD 4100.35)

Factor, Planning. A properly selected multiplier, used in planning to estimate the amount and type of effort involved in a contemplated operation. Planning factors are often expressed as rates, ratios, or lengths of time. (DOD 5000.8)

Fairway. The channels which must be left unobstructed for free navigation in a harbor.

Feet of Head. The measure of pressure in terms of the height in feet of a column of a given fuel. This measurement is convenient for use in hydraulic design of pipelines, since it can be applied directly to terrain elevations.

Field Army Depot. A supply unit under field army control which normally receives supplies from theater depots in the communications zone. Army depots have the mission of receiving, storing, and issuing supplies for the field army. (AR 320-5)

Fleet Capability. The amount of cargo, expressed in tons per day, that may be moved by a given unit fleet on a continuing basis, exclusive of any restriction imposed by the terminal facilities.

Floating Crane. A crane mounted on a barge or ponton. Almost any type of crane can be used; thus the variety and size of floating cranes are especially great.

Floating cranes may be either self-propelled or non-self-propelled, and the float may range from a simple wooden barge to an elaborate molded-steel hull with built-in balancing tanks and pumps.

Fork Lift Truck. A self-propelled vehicle having two or more prongs or tines which may be elevated and used for handling packaged, crated or baled cargo.

Forward Base. An overseas base (not the home station of the tactical unit concerned) which either has on it a tactical unit (or portion thereof) being supported or is located near such a base and furnishes materiel directly to such a unit. A base which is not the home base of the combat forces but will be used for war operations. Each base may be required for several uses simultaneously, such as staging turn-arounds, operating, and transit use. (AFM 67-1)

Function, Component. A clearly defined type of operations assigned to an "operating unit" in order to carry out a "primary function." For example, materiel receiving and issue functions of depot supply operations. Also, installation-support functions are component functions with respect to depot supply operations. (DOD 5000.8)

Functional Component. The smallest unit capable of performing a specific function, e.g., flat car for containers, tractor with operator, hatch gang. These units are building blocks used in forming a force, a train, a ship discharge unit, etc., for a specified mission.

General Cargo. Cargo which is susceptible for loading in general, non-specialized stowage areas, e.g., boxes, barrels, bales, crates, packages, bundles and pallets. (AR 320-5).

Cargo which is susceptible of loading in any place, such as boxes, bales, barrels, crates packages, bundles, and pallets. (JCS Pub. 1)

The pay load, freight or burden of a vessel exclusive of ship's stores, passengers, fuel and ballast, and consisting of articles in various forms and sizes, but capable of being loaded and unloaded by ship's gear and/or ordinary shore-based handling equipment.

Any commodity other than aircraft, ammunition and explosives, reefer, and special cargo.

General Depot. A supply establishment for the receipt, storage, and issue of two or more commodities or types of supplies.

General Supplies. Intraservice classification as applied to ordnance, quartermaster and transportation supplies. Ordnance general supplies include all ordnance supplies, with the exception of ammunition, required for the maintenance of an organization. Quartermaster general supplies include quatermaster materials and equipment required for housing, feeding and maintaining a command but excluding fixed installations in buildings, subsistence, fuel, clothing and individual equipment. Transportation general supplies include shelf items not ordinarily subject to special controls. (AR 320-5)

General Support. That support which is given the supported force as a whole and not to any particular subdivision thereof. (JCS Pub. 1)

Gravity, API. The gravity scale developed by the American Petroleum Institute to express the density of petroleum products. In this scale, water has a gravity of 10°API and liquids lighter than water, such as petroleum fuels, have API gravities greater than 10°.

Gravity, specific. The ratio of weight, per unit volume, of a given substance to the weight of the same volume of water. The specific gravity of substances lighter than water, such as petroleum liquid fuels, is less then 1.0.

Gross Vehicle Weight. Weight of a vehicle including fuel, lubricants, coolant, on vehicle materiel, payload and operating personnel. (AR 320-5)

Hatch. The opening in a ship's decks used for loading or discharging cargo. It is an opening from the hold up and an all-over hatch is carried through all the decks; a blind hatch is not.

Head, Terminal. Tank farm at a pipehead.

Height of Deck. The height of the wharf, pier, or quay deck above the water level at a specified datum.

High Water (HW). The maximum height reached by a rising tide. The height may be due solely to the periodic tidal forces, or it may have superimposed upon it the effects of prevailing meteorological conditions.

Highway Capacity. The number of vehicles or the number of short tons payload which can be moved over a highway with proper consideration of type of roadway, maintenance, hills, curves, weather, other traffic, type of vehicle employed, etc.

Maximum traffic flow obtainable on a given roadway using all available lanes. (AR 320-5)

Hydraulic Gradient Triangle. A right triangle so constructed that the slope of its hypotenuse represents the rate of pressure loss due to friction of a given fluid flowing through pipeline of a given size at a given initial pressure. Altitude of the triangle represents the initial pressure; base of the triangle represents the total length of pipe through which the fluid can be moved against friction alone by the initial pressure; when applied to the profile of the pipeline route drawn to the same scale, this triangle locates the point where pressure losses due to both friction and elevation require the location of another pump station.

Incremental Pressure. The difference between the suction and discharge pressure of a pump or of a multi-pump pumping station.

Index Number. A ratio of a numerical quantity or value of a subject item, or items, to the numerical quantity or value of a similar item or items taken as a standard for purposes of comparison. May be expressed as percent. For example: a price index of an item is the ratio of its price at a given time to its price at some other time, usually previously (and referred to as a base price or base-period price). (DOD 5000.8)

Infrastructure-Facilities. A generic term used to cover all fixed and permanent installations and facilities for the support and control of military forces. Excludes personnel, stores, and supplies to operate the installations and facilities. A term used generally in connection with NATO jointly sponsored support facilities. (DOD 5000.8)

Initial quipment. Prescribed TA and TOE equipment deployed with a unit.

Inland Waterway. A river, canal, lake, or other body of water, situated in the interior part of a country or region, used as a route or way of travel or transport. In the broad sense of the term, coastal routes utilizing protected bays, inlets, sounds, and connecting channels, such as the Atlantic and Gulf Sections of the Intracoastal Waterway in the U.S., may be considered inland waterways.

Interchange Fleet Equipment. Military owned railroad rolling stock registered for interchange service other than that permanently assigned to intrabase or intraplant operations. (AR 55-650)

Intertheater Traffic. Traffic between oversea command areas, exclusive of that between the United States oversea command areas. (AR 50-30)

Traffic between theaters exclusive of that between CONUS and theater. (AR 55-23)

Intratheater Traffic. Traffic within a theater. (AR 55-23)

Traffic within an oversea command, area or theater. (AR 50-30)

Length of Haul. The distance between the origin and destination in which cargo is moved (one way only).

Level of Service. A term which, broadly interpreted, denotes any one of an infinite number of differing combinations of operating conditions that may occur on a given lane or roadway when it is accommodating various traffic volumes. Level of service is a qualitative measure of the effect of a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort and convenience, and operating cost. In practice, selected specific levels are defined in terms of particular limiting values of certain of these factors.

A given lane or roadway may provide a wide range of levels of service. The various levels for any specific roadway are functions of the volume and composition of traffic and of the speeds attained. A lane or roadway designed for a certain level of service at a specified volume will actually operate at many different levels of service as the flow varies during an hour, and as the volume varies during different hours of the day, days of the week, periods of the year, and during different years with traffic growth. Further, different types of highways, roads and streets, such as freeways, expressways at grade, major multilane highways, local two-lane rural roads, urban arterial streets, and downtown streets, nearly always provide different levels of service that cannot be directly related to one another because each must be measured by a different standard or scale.

Lightering. The transshipment between ships and wharves of commodities or passengers, by floating equipment.

Line Haul. Transportation of freight over the tracks of a railroad or over the routes of a trucking company from point of origin to the destination, excluding local pickup, delivery and switching. (DSAR 4500.3)

Transportation of freight over the tracks of a railroad or over the routes of a trucking company, airline, or steamship company from point of origin to the destination excluding local pickup, delivery and switching (DOD 4500.32-R)

In highway transportation, a type of haul involving long trips over the road wherein the proportion of running time is high in relation to time consumed in loading and unloading. Line hauls usually are evaluated on the basis of ton miles forward per day. In rail transportation, this term applies to the movement or carriage of material over tracks of a carrier from one point to another, but excluding switching service. (AR 320-5)

Link (Arc). That portion of a route lying between, or connecting, two nodes.

Lock. The system of valves, wet docks and watergates permitting ships to pass from a higher to lower or a lower to a higher water level.

Locking Cycle. The time required for the passage of craft through a lock and the return of craft in the opposite direction, returning the lock to its original state.

Logistics Over the Shore Operations. The loading and unloading of ships without the benefit of fixed port facilities, in friendly or non-defended territory, and, in time of war, during phases of theater development in which there is no opposition by the enemy. (JCS Pub. 1)

Low Water (LW). The minimum height reached by a falling tide.

Major End Item. A final combination of end products, component parts and/or materials which is ready for its intended use, e.g., ships, tank, mobile, shop, aircraft. (SECNAVINST 4423.8, AR 701-5).

A finished item complete within itself, whether a simple piece or made up of many pieces, and ready for its intended use. Often used as a cataloging term in supply. (AFM 67-1)

Major Port. Any port with two or more berths and facilities and equipment capable of discharging 100,000 tons of cargo per month from oceangoing ships. Such ports will be designated asprobable nuclear targets. (AR 320-5 JCS Pub. 1)

Marginal Wharf. A berthing structure, usually supported by open piling and built against and parallel to the shoreline.

Materials Handling Equipment. A self-propelled engine or motor drive vehicle designed to facilitate the handling of material in warehousing, loading and unloading. (DOD 4150.2)

A self-propelled item of equipment designed for lifting, moving and placing material within a warehouse or a specific area. Under this category are self-propelled materials handling equipment such as gasoline, diesel, or electric-powered forklifts and trucks and similarly powered warehouse towing tractors, gasoline or electric-powered platform lift trucks and wheeled warehouse cranes; straddle trucks; and pallet-type gasoline and electric-powered cargo transporters. (AFM 66-12)

Mechanical devices for handling of supplies with greater ease and economy. Examples: forklift truck, roller conveyor, straddle truck. (AR 320-5)

Forklift trucks, towing tractors, warehousing industrial cranes, straddle-carry trucks, pallet trucks, platform trucks, warehousing trailers, and conveyor systems, used in storage and handling operations. (NAVSUP Pub. 284).

Materiel. All items of personal property necessary for the equipment, maintenance, operation and support of military activities without distinction as to their application for administrative or combat purposes; excluding ships or aircraft. (DOD 4000.19)

All tangible items (including ships, tanks, self-propelled weapons, aircraft, etc., and related spares, repair parts and support equipment; but, excluding real property, installations, and utilities) necessary to equip, operate, maintain, and support military activities without distinction as to its application for administrative or combat purposes. (AFR 66-1, DOD 3232.1, DOD 4151.1, DOD 7220.21)

All items of personal property necessary for the equipment maintenance, operation, and support of military activities without distinction as to their application for administrative or combat purposes. (DOD 4140.36, AFM 67-1, DOD 5000.8)

All items necessary for the equipment maintenance, operation, and support of military activities without distinction as to their application for administrative or combat purposes; excluding ships or naval aircraft. (AFM 11-1, AR 320-5, JCS Pub. 1)

All items necessary for the equipment maintenance, operations, and support of military activities without distinction as to their application for administrative or combat purposes. (AFR 84.2)

Mean High Water Springs (MHWS). The average height above datum of high waters occurring at the time of spring tides as determined over a long period of time.

Mean Low Water (MLW). The average height of all low waters in any locality as determined over a considerable period of time.

Mean Low Water Springs (MLWS). The average height of low waters occurring at the time of spring tides. It is usually derived by taking a plane depressed below the mean tide level by an amount equal to one-half the spring range of tide, necessary corrections being applied to reduce the result to a mean value. This plane is used to a considerable extent for hydrographic work outside the U.S.

Mean Range of Tide. The difference in height between the mean of all high waters and the mean of all low waters.

Mean Sea Level (MSL). The average height of the surface of the sea for all states of the tide, usually determined from hourly readings over a period of 19 years.

Media. Types of transportation vehicles or carriers. This includes trucks, rail cars, pipe, aircraft, barges, etc.

Mode. A specific transportation routing. Major modes include highway, air, rail, inland waterways, pipeline, intertheater ocean, etc.

Node. The intersection of two links, an origin or destination, the point of change of mode characteristics, or a transfer point.

Offshore Wharf. A berthing structure usually supported by open piling and built parallel to but in an insular position off the shore and connected to it by one or more approaches or gangways.

Open Waterway. A natural stream or artificial canal in which there are no man-made obstructions such as locks and dams or shiplifts.

Outsize Cargo. All wheeled equipment and all other items of cargo, programmed for transportation by any mode, for which any single dimension exceeds 100 inches in length, 74 inches in width or 67 inches in height, or exceeds 10,000 pounds in weight. (TACM 400-1)

Packed Line. The condition in which the pipeline is kept full of product and under positive pressure whether the pipeline is operating or not.

Packaged Products. Petroleum products stored, transported, and issued in drums, cans, and similar containers as distinguished from bulk products.

Pier. A vertical support of an engineering structure. A wharf running at an angle with the shoreline of the body of water, providing a landing place to discharge cargo, passengers, stores or fuel.

Pipehead. The tanks, pumps, bulk reduction and other facilities at the downstream end of a pipeline where fuel is transferred to other transport media for distribution to users or Class III supply points.

Pipeline System. One or more pipelines with appurtenances organized and operated by the same controlling headquarters.

Planning Factor (Logistics). A properly selected multiplier, used in planning to estimate the amount and type of effort involved in a contemplated operation. Planning factors are often expressed as rates, ratios, or lengths of time. (AR 320-5, AFM 11-1, JCS Pub. 1)

Port Throughput Capacity. A planning factor used in determining the volume of cargo and/or passengers a marine terminal can handle and clear in one day, expressed both as a loading and unloading capacity. Normally the factor to be used will represent reception capacity, clearance capacity or storage capacity, whichever presents the most severe terminal limitation. (AR 320-5)

Prevailing Conditions. The capacity of a roadway depends on a number of conditions. Composition of traffic, roadway alinement, and number and width of lanes are a few of those conditions which may be referred to collectively as the prevailing conditions.

The prevailing conditions may be divided into two general groups -- (1) those that are established by the physical features of the roadway, and (2) those that are dependent on the nature of traffic on the roadway. Those inthe first group, none of which change unless some construction or reconstruction is performed, are referred to as the prevailing roadway conditions. Those in the second group, any of which may change or be changed from hour to hour or during various periods of the day, are referred to as the prevailing traffic conditions.

In addition to these prevailing roadway and traffic conditions, ambient conditions are present during all traffic flows. These conditions relate primarily to weather and include measures such as clear, dry, cold, warm, hot, rain, snow, fog, smog, smoke, wet, or icy pavement, and wind. Visibility during different hours of the day, particularly in daylight as compared to dark, also is an ambient condition. These conditions affect the ability of a roadway to accommodate traffic.

Prime Airlift. The number of aircraft of a force that can be continuously maintained in a flow from home base to onload base to offload base, hence to the recycle base. Spare and self-support aircraft are not not included. (AFM 11-1).

Productivity. Average number of work units produced per component over a definite period of time (day, week, month, etc.). (AR 320-5)

The actual rate of output or production per unit of time worked, when compared to a prior output rate on a measurable basis. (AFLCM 25-3)

Pumping Station. The combination of two or more pumps with connecting manifolds.

Quayed Breakwater. A solid wall structure built against and parallel to the inner or protected side of an artificial embankment designed to break the force of the sea and to furnish shelter behind it. The top of the quay may support railroad tracks, buildings and mechanical handling equipment.

Rail Organization. Each of the transportation railway supervisory and command units is capable of supervising and operating a railway service within the stated capability of the unit. This provides flexibility in organizing a transportation railway service since theater requirements may be met by an organization ranging from that requiring a general headquarters as the senior railway unit down to a limited operation in which a battalion, as the largest railway unit, would operate a system of 90-150 miles (145-242 kilometers) in length.

Range of Tide. The difference in height between consecutive high and low waters; also the average of any number of such differences. The mean difference between all high waters and all low waters over a considerable period of time is known as the mean range and the mean difference between the higher high waters and the lower low waters is known as the great diurnal range.

Reefer. Perishable commodities such as meats, vegetables, fruits, butter, eggs, and poultry, which require refrigerated (chill or freeze) storage at prescribed temperatures while in transit to prevent deterioration or loss. Does not include semiperishable cargo stored in ventilated holds.

Requirements. The need or demand for personnel, equipment, facilities, other resources, or services, by specific quantities, for specific periods of time or at specified times. (DOD 5000.8)

The plan or statement indicating the need or demand for personnel, equipment, supplies, resources, facilities, or services by specific quantity for specific periods of time or at a specific time. (AR 310-44)

Resource Census. A detailed descriptive inventory of inland waterway craft, highway or rail equipment, or materials handling equipment of a host nation. It may also include an inventory of available labor and facilities. Military resources are part of the troop list and are treated separately.

Resource, Transportation. The men, equipment and facilities necessary for the handling and transportation of passengers and cargo.

Retail Supply Point. An activity of a military service where material is received, stored, and issued to using units. (AFLCM 72-2)

Road Net. The system of roads available within a particular locality or area. (JCS Pub. 1)

Rolling Stock. Rolling stock is assigned to the transportation railways groups and will be used over the entire system. Work equipment may be assigned to transportation railway battalions as required for use on their divisions.

Root of Pier (also foot of pier). The shore or land connected end of the pier. The opposite end from the head end.

Safe Draft. The maximum vertical distance between the water surface and the lowest part of a vessel feasible on a given water course with reasonable assurance of not grounding while navigating.

Shipment. A line item or group of line items packed, marked, and documented for movement to a single consignee as identified by the requisitioner, supplementary address, and project codes. A shipment normally is limited to a single transportation conveyance. (AR 725-50)

A consignment of goods from one place, furnished under one contract or subcontract and released to a carrier for transportation to a single destination. (CNMINST 5000.3)

Ship's Tackle. Blocks, rigging, and other working gear employed on a ship for hoisting cargo.

Slack Line. The condition in which the pipeline is not operating and may or may not be full of product; and in which that part of the line containing fuel is subject only to static pressure.

Special Cargo. All wheeled and tracked vehicles and any commodity which weighs more than 10,000 pounds or measures 35 feet or more in any dimension.

Stacking Space. Usually flat, unoccupied areas adjoining or readily available to the wharves and provided with road and/or railroad exit, and usable for the placing of general cargo in packages, tiers or layers, while awaiting movement to other locations.

Stevedore Gang. A group of workers who load or discharge cargo carrying craft.

Storage. The safekeeping of goods in warehouse or other repository. Also the charge made for the care and responsibility of keeping goods in storage. Warehouse storages are usually based on a monthly rate which is charged for the month or fraction thereof, although storage periods may range for any period from one day to one year.

Stowage Factor. Relationship between measurement of cargo and weight of cargo. This relationship is based upon 40 cu. ft. per ton.

Volume measurement varies from 9 cu. ft. per ton for pig iron to 1,000 cu. ft. for unnested wicker baskets. This would result in a corresponding stowage factor ranging from .225 to 25.0.

Submode. Any part of a transportation mode, e.g., lighter transport, helicopter transport, etc.

Switch Engines. Switch engines are assigned to yards and terminals according to the following general criteria:

(1) Installations and depots -- one per 67 cars dispatched and received per day.
(2) Railheads -- one per 67 cars dispatched and received per day.
(3) Intermediate yards and handling terminals -- one per 100 cars passing or handled per day.

Tactical Airlift. The means by which personnel, supplies and equipment are delivered by air on a sustained, selective, or emergency basis to dispersed sites at any level of conflict throughout a wide spectrum of climate, terrain, and conditions of combat. Air Force tactical airlift forces enhance the battlefield mobility of the Army in ground combat operations by providing a capability to airland or airdrop combat elements and providing these forces with sustained logistical support. Air logistic support permits rapid delivery with a minimum of trans-shipments from source to final user destination. In furtherance of the combat mission of the Army, the Air Force will sustain an Air Line of Communication to division and brigade bases and will deliver to lower echelons when required by tactical considerations. (AFM 11-1)

Tank Farm. Actually one or more than one storage tank, but generally a group of storage tanks connected to a pipeline or dispensing or bulk reduction facility.

Terminal. (1) The end of a transportation movement, also terminus. (2) A structure, or group of structures operated as a single unit, located at a point of interchange between land and water carriers, or air and surface carriers, and used for handling and care of passengers and/or freight. (3) The freight sheds and passenger stations at a railroad terminus.

Towing Capability. The amount of cargo, expressed in tons per day, that can be propelled by tug, towboat, pushboat or self-propelled barge, exclusive of any restrictions imposed by the terminal facilities or cargo carrying fleet.

Towing Craft. Inland waterway craft (such as powered tugs, towboats, pushboats or self-propelled barges, sailing vessels, and manually-propelled craft) used to propel dumb craft.

Tracks. On single track lines, passing tracks are generally 6 to 8 miles apart. Multiple tracks (three or more) are generally considered as double track since it is often necessary to remove a portion of all of the third and fourth tracks to maintain a double track line.

Train Density. The number of trains that may be operated safely over a division in each direction during a 24-hour period.

Transfer (transshipment). The removal of cargo from one mode and placing it on another, e.g., rail to highway, IWW to highway, etc.

Transit Shed. Wharf structure for the short time storage and sorting of merchandise in transit.

Transport Network. The complete system of the routes pertaining to all means of transport available in a particular area. It is made up of the network particular to each means of transport. (JCS Pub. 1)

Turnaround Time. The estimated number of days required for a car to make a complete circuit of the rail system. It is the days elapsed from the time the car is placed at the point or origin for loading until it is moved to its destination, unloaded, and re-returned to its point of origin. Such time may be computed as follows: 2 days at origin, 1 day at destination, and 2 days transit time for each division or major portion thereof, which the cars must traverse (1-day forward movement, 1-day return movement). This method, rather than an actual-hour basis, is used to incorporate delays due to terminal and way station switching as well as intransit rehandling of trains.

Turnaround Time. The time required for vehicles or inland waterway craft to make a round trip between two points.

Vehicle. A self-propelled, boosted, or towed conveyance for transporting a burden on land, sea, or through air or space. (JCS Pub. 1, DOD 4500C.-32-R)

Viscosity. The measure of internal friction of a substance, its resistance to flow. Viscosity varies with temperature; as the temperature rises, viscosity decreases.

Viscosity, kinematic. The absolute viscosity of fluid divided by its density. The resulting number is referred to as the kinematic viscosity of the fluid.

Waterway Facility. All arrangements, means, structures, or group, or series of structures used to facilitate the handling or passage of cargo and passengers at a waterway terminal or along the water route.

Waterway System. A group or series of interconnected rivers, canals, lakes, or other bodies of water, used as an integrated route or way of travel or transport.

Wet Dock. An artificial basin in which water is retained by caissons or gates and is kept at a certain level. The entrance is frequently through a lock. The wet dock is used where tidal ranges are great,

particularly in northwestern Europe. The dock walls are quayed for alongside berthing.

Wharf. A berthing place for vessels to facilitate direct loading and discharge. Place for loading or unloading ships or vessels, usually a platform of timber, stone, or other material, along the shore of a harbor or bank of a navigable river, against which vessels may lie and discharge their cargo or be loaded. Piers and quays are distinctive forms of wharves.

Working Space. That space on a wharf, quay, or pier necessary for the cargo handling operation, including the apron and transit shed. In the event there is no transit shed, the open space to the rear of the apron.

Workload. The amount of work in terms of predetermined work units which organizations or individuals perform or are responsible for performing. (TM 38-750-1, DOD 5000.8)